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Nuts & Volts

November 2004

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- Designing Good PCBs
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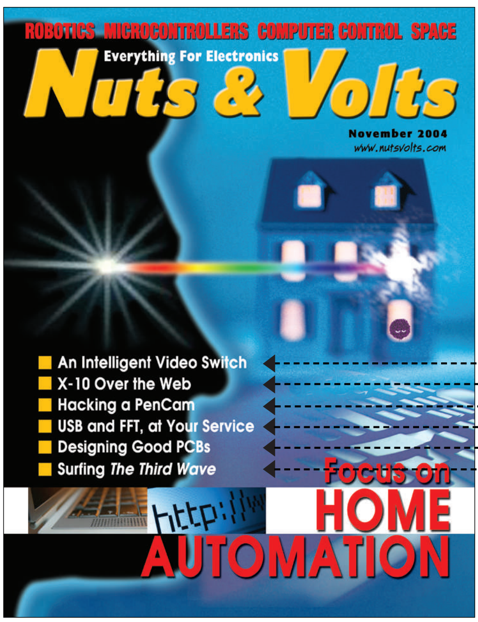

DEPARTMENTS

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Reader Feedback

Dear Nuts & Volts:

I was a bit dismayed when I read the "Digital Over Power Line Standard Under Development" write-up in "TechKnowledgey 2004" in the October issue and found that it made no mention as to how potentially damaging to amateur radio and shortwave radio listening broadband-over-power-lines (BPL) it would be.

BPL would be an outrageous misuse of technology and yet another contributor to environmental pollution. Broadband Internet connectivity (which this household cherishes) belongs within the domain of coaxial cable, optical fiber, or satellite dish — not unshielded house wiring. It is an outrage to think of allowing portions of the nation's power grid to act as a gigantic antenna for the propagation of wide spectrum (digital) HF interference into the environment. The ARRL (Amateur Radio Relay League) has mounted a strong campaign against BPL interference. For more information, see: **www.arrl.org/tis/info/HTML/plc/**

Additionally, the Federal Emergency Management Agency (FEMA) has filed statements with the FCC saying that BPL could, "severely impair FEMA's mission-essential HF (high frequency) radio operations." In a word, BPL could disrupt radio communications in a national emergency. If BPL were to succeed, it could contribute significantly to the decline in interest in amateur radio and ultimately to the absence of the trained amateur (HAM) radio community and its participation in times of regional or national emergencies, not to mention the demise of what many regard as the "king of hobbies."

Lawrence Gruber
Medford, MA

Jeff Eckert responds:

My presumption is that the IEEE P1675 standard — which isn't scheduled for publication for almost two years — will have to address the EMI/RFI problems. The IEEE EMC Society (of which I was a member for several years) should certainly be involved.

The point of the blurb was to invite interested parties to help develop the standard, not to promote any particular approach. I have no dog in the fight. If BPL can be made practical, great. If not, we'll just have another standard out there that is never translated into hardware. Having a standard doesn't guarantee commercial success.

The concept reminds me of the old carrier-current AM transmitters that I ran into in the 1970s. These also had problems, but served some niche markets. I don't know if anyone uses them anymore.

Dear Nuts & Volts:

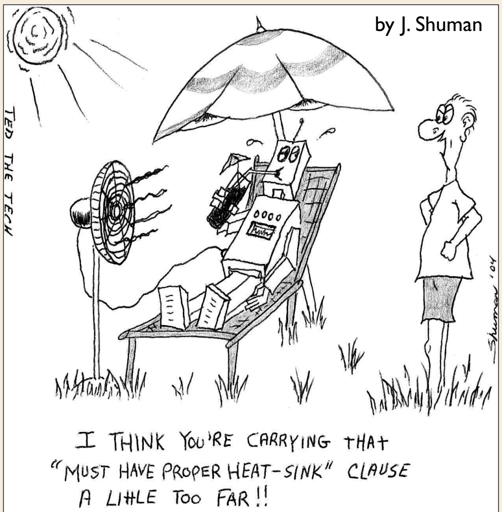
I really enjoyed Sarah Lowrey's interesting and informative article about early transistor radios. Readers might also want to visit **www.ChildhoodRadios.com** a website run for and by collectors of vintage electronics from the 50s and 60s.

The site hosts a streaming video of the manufacture of Regency TR-1s. There is also a very active message board with posts by newcomers and old pros, links to radio museums, personal collections, sources of restoration parts, schematics, and much more.

Ron Mansfield
via Internet

(Continued on Page 37)

by J. Shuman



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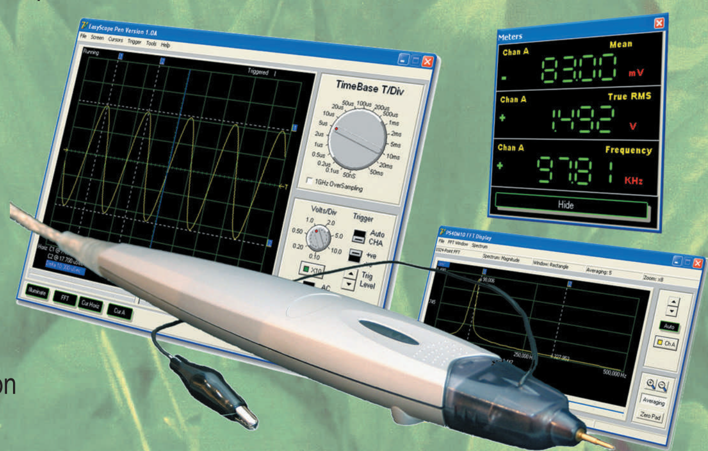

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NEW!

Micro Memories

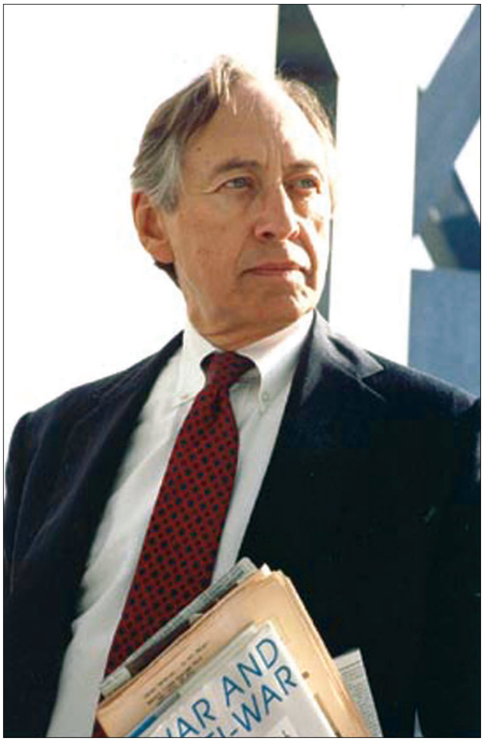
25 Years Into the Future — 1980s *The Third Wave*

Many science and science fiction writers have written books that predict the future. By the 1970s, a term was coined for these sorts of authors: futurists. Few books, however, got the future — the future that we're living in right now — as right as Alvin Toffler's *The Third Wave*, which celebrates its 25th anniversary in 2005.

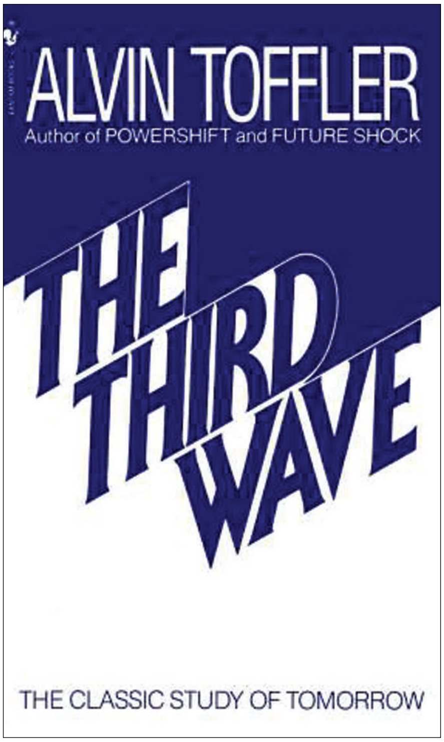
Toffler explained how he coined that title to *Wired* magazine in 1995. "The reason we chose the phrase 'third wave' rather than saying 'the information age,' or 'the computer age,' or 'the space age,' or whatever is that the changes we denominate as the third wave are changes in every aspect of the civilization. We thought that, by saying 'computer age' or 'digital age,' we'd be focusing on a single parameter. The second thing about waves is, you can have more than one wave of change moving through a society at the same time."

The first wave was the agriculturally-based economy that lasted from approximately 8000 BC until 1750 AD. The second wave was the Industrial Revolution, which Toffler defines as running from then until 1955, after which the third wave began. Toffler used 1955 to mark the approximate beginning of the third wave, since that was the first year that white-collar and service workers began to outnumber blue-collar workers.

Alvin Toffler, vanguard futurist.



Toffler's sequel to *Future Shock*.



Surprising Optimism in the Worst of Times

How many things did Toffler get right? Quite a few, actually: networked computing, telecommuting, flex-time, the end of the dominance of mass media, standardized mass production replaced with customization, and even the smart, automated home.

The Third Wave was a sequel to Toffler's 1970 book, *Future Shock*, which became a surprise runaway bestseller. While that book seems somewhat dated by the influence of the psychedelic late 1960s, what's surprising is how optimistic of a work its sequel is, especially considering the period that it was written in.

The late 1970s was the very trough of America's post World War II economy, when interest rates, unemployment, and inflation were all at or approaching double digits. Jimmy Carter gave his famous "malaise" speech. Fifty-two American hostages were being kept in Iran by forces of radical Islam. It was the worst of times; it was the worst of times.

Yet, through astute research and forecasting, Toffler was able to foresee the progress that mankind would be making as technology accelerated the rate of change. Part of the reason why the late 1970s economy was so bad, Toffler argued, was that the economy itself was making a transition from a manufacturing-based "rust belt" and assembly line economy to an information-driven economy.

The Computer Replaces the Machine

The computer was about to replace the machine as the dominant force in society; this had enormous implications. The machine powered the assembly line, which mass produced products for mass consumption. It powered the printing press, which mass produced newspapers. It lead to the creation of simple, one-way — but powerful — media, such as radio and TV: mass production, mass media ... and mass men, who went to work using mass transit and dressed alike, in mass produced suits and ties.

The computer smashed all of that. Mass production was replaced by personalized customization. Today, CaféPress (**www.cafepress.com**) will take any image uploaded to them and put it onto clothes, cups, lunch boxes, and toys. They don't care if one customer buys it or tens of thousands.

For 40 years, the media meant three commercial nationwide television networks and a dwindling number of big city newspapers whose stories were dominated by material that originated in *The New York Times* and *The Washington Post* and three wire houses: AP, UPI, and Reuters.

That all changed, first with cable TV and satellite TV, which replaced three networks — who had to cater to a hundred million viewers — with hundreds of channels, many of which focused on extremely narrow interests. (Ted Turner — who created CNN — the first 24-hour news channel, directly cited Toffler as an influence.)

Then the Internet went online in 1969. Once the graphic-laden World Wide Web began to ride on top of it in the early 1990s, it further broke up the mass media and allowed literally anyone to create their own publishing — and even broadcasting — house.

Even in 1980, starting a magazine or a TV channel cost money — and lots of it. Today, anyone can go to **www.blogger.com** and start their own weblog and put any content they want on it: text, still photos, videoes, or audio clips.

Over seven million people have done so, with content ranging from personal diaries to news, sports, and political analysis. Between the writers and their readers, those numbers are larger than what *The New York Times* has or CNN and Fox News, combined.

Why 2004 Isn't Like 1984

This is why it's kind of ironic to watch science fiction films in the years prior to *Star Wars*. Does everyone dress the same and wear the same shaved heads like the cast of *THX-1138*? Do gigantic corporations dominate business, like in *Rollerball*? Not really; look how many solo entrepreneurs, consultants, and small business owners there are — far more than in the mid-1970s. Even after the

dot.com bust of 2000, there are plenty of solo entrepreneurs and one-man news sites on the web.

Even for those who aren't information moguls, this technology has radically transformed lives. *The Third Wave* also predicted what Toffler dubbed "the electronic cottage." In the late 1970s, few homes had VCRs, fewer still had a personal computer, cable TV was still rather rare, and most homes had communications technology scarcely advanced since the mid-1950s: radio, TV, a record player, and a single line telephone. Today, the average den contains a PC with a broadband Internet connection, a wired or wireless LAN to the rest of the house, multiple phone lines, hundreds of channels of satellite or digital cable, DVDs, CDs, and increasingly, an MP3 server. That's a staggering amount of communications and computing technology.

Is there a fourth wave on the way? In recent years, Toffler has theorized what it could be and when it will arrive: "some decades away — when we have fully merged or married information technology and bio-technology. That will be, in a certain sense, a preparation of the human race for the spread of the human species — in whatever form that species is — onto other planets.

"That sounds like science fiction," Toffler is quick to add, but so did much of what he wrote 25 years ago. **NV**

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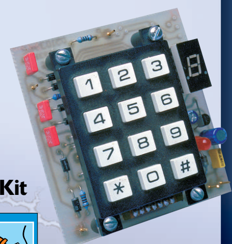

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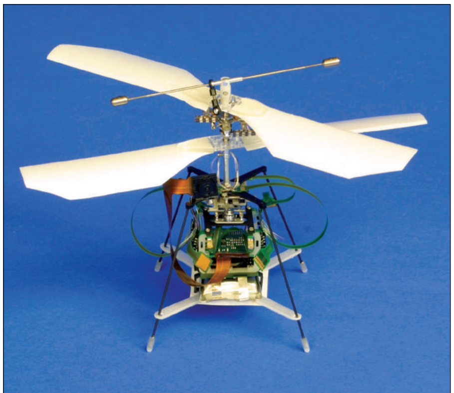
Events, Advances, and News From the Electronics World

Advanced Technologies

World's Smallest Flying Robot



The µFR-II flying robot features increased lift and Bluetooth communications. Photo courtesy of Seiko Epson Corp.

Seiko Epson (**www.epson.com**) recently demonstrated an updated version of its Micro Flying Robot (µFR), which is believed to be the world's smallest and lightest device of its type. The original model featured two ultra-thin, ultrasonic motors driving two contrarotating propellers for levitation, plus a linear actuator stabilizing mechanism for altitude control during flight.

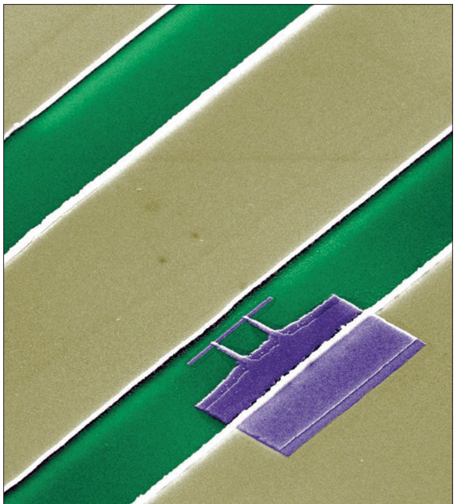
The downside was that the microrobot's flying range was limited by the length of the power cord attaching it to an external battery and — although it was radio controlled — it had to be kept within sight of the operator while flying. Epson decided that the next step was to extend the flying range by developing fully wireless operation paired with independent flight capability, which would require a combination of lighter weight and greater dynamic lift.

This was accomplished with a new gyro-sensor that is one-fifth the weight of its predecessor and a high density mounting technology used to package the microrobot's two microcontrollers. Dynamic lift was boosted 30% by introducing more powerful motors and newly designed main rotors. To allow independent flight, Epson developed a linear actuator with faster response time and a high precision altitude control mechanism, plus a flight path control and independent flight system (primarily for hovering).

The µFR-II also includes an image sensor unit that can capture and transmit aerial images via a Bluetooth wireless connection to a monitor, plus two LED lamps that can be controlled as a means of signaling. Its physical dimensions have been reported as 136 mm diameter and 85 mm high, with a total weight of 12.3 g, including the battery. Power consumption is 3.5 W. Although the unit is still in the prototype stage, later versions could be marketed for entertainment and even surveillance applications.

Epson was assisted by Chiba University's Nonami (Control and Robotics) Laboratory in developing the control system for independent flight. The company also received advice on the rotor design from the Kawachi (Aeronautics and Astronautics) Laboratory at the University of Tokyo.

Artificial Molecule on a Chip



In circuit QED experiments, a photon trapped between the transmission lines (light diagonal stripes) couples to the artificial atom or qubit. The base of the qubit is about 9 µm long. Photo courtesy of D. Schuster and L. Frunzio, Schoelkopf Group, Yale University.

Using IC fabrication techniques, researchers from Yale University (**www.yale.edu**) have reported binding a single photon to a superconducting device engineered to behave like a single atom, forming an artificial molecule. It's the first experimental result in a field Yale professors Robert Schoelkopf and Steven Girvin have dubbed "circuit quantum electrodynamics."

The superconducting devices can be operated as qubits, the basic element of information storage in the field of quantum computing. The qubit couples to a microwave photon, sharing energy in much the same way that electrons are shared when two atoms combine to form a molecule. The professors have offered two suggestions for naming the new, combined state: phobit or quton.

Qutons have been made before, the first about 12 years ago. However, by using artificial atoms for

their qubits instead of real ones and microwave transmission lines instead of optical cavities, the Yale physicists were able to shrink a roomful of experimental apparatus onto a chip less than 1 sq cm in size. They have also improved the coupling between resonator and "atom" by a factor of about 1,000, which will help them explore fundamental interactions of light and matter. The next step is to try to control several qubits on one chip using photons to connect them together in a prototype architecture for quantum computing and quantum cryptography.

Computers and Networking

"World's Thinnest Desktop" Introduced

Apple's latest i-Mac combines the display and CPU in one compact package, leading the casual observer to wonder where the computer went. Photo courtesy of Apple.

It looks like a giant iPod, but it's really the newest version of the iMac® from Apple (**www.apple.com**). It's main claim to fame is that the entire CPU is built into the flat panel display, which is only 2 inches thick and stands on a single aluminum foot. The design includes a slot-load optical drive and you have the option of plugging wires into the I/O ports (three USB and two FireWire®) along the right rear side or going wireless with AirPort® or Bluetooth modules.

Two versions are available, providing a choice of 17 inch or 20 inch displays. Both can be had with a 1.8 GHz, 64 bit PowerPC G5 processor, but — for the frugal — there is a 1.6 GHz option, available only on the 17 inch model. They are offered with the usual standard and optional features, including built-in stereo speakers and a microphone, a SuperDrive (DVD-R/CD-RW), Ethernet, a 160 GB hard drive, and up to 2 GB of 400 MHz DDR RAM. As usual, style doesn't come cheap. Prices run from $1,299.00 to $1,899.00.

Explore the Universe for $79.95

If you have an interest in astronomy, but can't afford to build your own observatory, you may be interested in Starry Night Enthusiast v. 5.0, from Imaginova Corp. Billed as the world's most realistic astronomy software, it allows you to see the sky from anywhere on Earth or lift off and visit any solar system body or location up to 20,000 light years away. You can view 2,500,000 stars along with 170+ deep space objects, including galaxies, star clusters, and nebulae, and you can travel 15,000 years in time, experience the view from the International Space Station, and see planets up close from any of their moons.

You get more than 2.5 hours of movies on both the CD-ROM and a bonus DVD. To run the software, you need a Windows 98/ME/2000/XP-based machine with a 500 MHz or higher processor, 400 MB of spare drive space, and an OpenGL-capable graphic card. Mac owners must have OS X 10.1 or higher and the same amount of drive space. Details are available at **www.starrynight.com**

New Search Engine Offers Giveaways

Reportedly, Google receives 250 million queries and Yahoo! performs 240 million searches every day. Google rakes in $100+ million annually and Yahoo! collects double

that amount. You get to use their search engines for free, which isn't a bad thing. The people at FindIsland (**www.findisland.com**) — a new search site being launched — want to share the wealth with you. Well, at least a little bit of it.

After signing up to use the service, you are credited with a point for each search you conduct, subject to a limitation of 10 points per hour and 30 points per day. Each point equals a chance to win a monthly prize and, at some unspecified time, there may be weekly or daily prizes, as well.

Before you get too excited, though, consider that the monthly plums mentioned by FindIsland include iPods and X-Box game machines, not Ferraris or yachts. If you log your maximum 30 points per day, at the Google traffic level, your chance of winning would be 1 in 8.3 million. (By comparison, the average chance of being struck by lightning is 1 in 600,000.)

The odds would improve a bit with weekly and daily prizes, but the loot being dangled before you at this level includes things like free Blockbuster movie rentals, lottery tickets, and Britney Spears CDs. This looks like the Ebeneezer Scrooge concept of sharing the wealth.

On the other hand, any chance is better than none and FindIsland is powered by Google, anyway, so what's the difference? If you turn out to be the big winner, you can always throw away the Britney CD and use the jewel case for something else.

Circuits and Devices

6 GHz Handheld Spectrum Analyzer

The FSH6 handheld spectrum analyzer operates up to 6 GHz. Courtesy of Rohde & Schwarz.

Rohde & Schwarz (**www.rohde-schwarz.com**) has expanded the frequency range of its handheld spectrum analyzer to 6 GHz, thus making it suitable for WLAN 802.11a applications, as well as general lab applications in higher frequency ranges. The R&S FSH6 includes user-friendly menu guidance and can be tuned by means of channel numbers instead of frequencies, which facilitates operation for many users from mobile radio and broadcasting.

The instrument is available in two versions with a frequency range from 100 kHz to 6 GHz. The integrated tracking generator makes the instrument useful for scalar and vector network analysis, distance-to-fault measurements, and one-port cable loss measurements.

In many cases, however, the R&S FSH6 can also be used without a tracking generator for installing, optimizing, and servicing WLAN 802.11a networks or in general lab applications. Moreover, the R&S FSH6 tests the frequency and level of local oscillators in mobile radio telephones between 3.4 GHz and 3.9 GHz and is, thus, also ideal for use in repair stations. Small doesn't necessarily mean inexpensive, though; the list price is $11,890.00.

Jumbo LED

The Lumex SSI-LXH2001 LED indicator can be seen from distances of up to 100 ft. Photo courtesy of Lumex, Inc.

Bucking the concept that smaller is better, Lumex, Inc. (**www.lumex.com**), has introduced an LED indicator that, by virtue of its 1 inch (25.4 mm) lens, can be seen at distances of up to 100 ft (30.5 m).

The LED behind the lens is made up of six chips that can be driven with 30 mA at a forward voltage of 10.5 to 12.0 VDC. The indicator can be installed in panels 1.5 to 4.0 mm thick, inside a 27.1 mm cutout.

Standard colors are available — from blue to red and white. Bicolor models are also available. The devices are designed primarily for industrial and process control annunciator panels, but can be applied to many other purposes.

Industry and the Profession

Solar Grants Awarded

The development of solar cells just received a boost at the R&D level, courtesy of the Defense Advanced Research Projects Agency (DARPA, **www.darpa.gov**), which recently announced that three companies and a research lab will compete to develop the technology. The solar project is overseen by DARPA's Microsystems Technology Office, which received proposals from more than 100 companies.

Receiving nods and major funding are Nanosolar, Inc. (**www.nanosolar.com**), which received a $10.3 million contract, Konarka Technologies, Inc. (**www.konarkatech.com**), $6.1 million, and Nanosys, Inc. (**www.nanosysinc.com**), $2.3 million. The fourth participant is the National Renewable Energy Laboratory (**www.nrel.gov**), which is part of the US Energy Department.

Nanosolar develops roll-printed solar electricity cells. It is collaborating with Lawrence Berkeley and Sandia National laboratories on next generation solar cells. Nanosys is using inorganic nanostructures to develop new solar energy sources, and Konarka's nanomaterials technology absorbs sunlight and indoor light and converts it into electricity.

Printers Recalled

If your toes begin to sizzle every time you touch your printer, it might be among ~40,000 defective ones that were sold between May and August.

The units are being recalled by the manufacturer, Lexmark, because of a short circuit hazard. Recalled printers include Lexmark E232, E232t, E330, E332, E332n, and E332tn, IBM Infoprint 1412 and 1412n, and Dell 1700 and 1700n models.

You are advised to disconnect the printer from the power source before checking to see if you own this model and do not insert your fingers into the device if it is powered via an ungrounded outlet. For details, log onto **support.lexmark.com/cgiperl/recall.cgi?ccs=229:1:0:0:0:0** **NV**

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Professional FM Stereo Radio Station

- ✔ Synthesized 88-108 MHz with no drift
- ✔ Built-in mixer - 2 line inputs, 1 mic input
- ✔ Line level monitor output
- ✔ High power version available for export use

The all new design of our very popular FM100! Designed new from the ground up, including SMT technology for the best performance ever! Frequency synthesized PLL assures drift-free operation with simple front panel frequency selection. Built-in audio mixer features LED bargraph meters to make setting audio a breeze. The kit includes metal case, whip antenna and built-in 110 volt AC power supply.

FM100B	Super-Pro FM Stereo Radio Station Kit	$269.95
FM100BEX	1 Watt, Export Version, Kit	$349.95
FM100BWT	1 Watt, Export Version, Wired & Tested	$429.95

Professional 40 Watt Power Amplifier

- ✔ Frequency range 87.5 to 108 MHz
- ✔ Variable 1 to 40 watt power output
- ✔ Selectable 1W or 5W drive

At last, the number one requested new product is here! The PA100 is a professional quality FM power amplifier with 30-40 watts output that has variable drive capabilities. With a mere one watt drive you can boost your output up to 30 watts! And this is continuously variable throughout the full range! If you are currently using an FM transmitter that provides more than one watt RF output, no problem! The drive input is selectable for one or five watts to achieve the full rated output! Features a multifunction LED display to show you output power, input drive, VSWR, temperature, and fault conditions. The built-in microprocessor provides AUTOMATIC protection for VSWR, over-drive, and over-temperature. The built-in fan provides a cool 24/7 continuous duty cycle to keep your station on the air!

PA100	40 Watt FM Power Amplifier, Assembled & Tested	$599.95

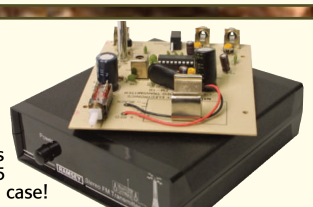
Synthesized Stereo FM Transmitter

- ✔ Fully synthesized 88-108 MHz for no drift
- ✔ Line level inputs and output
- ✔ All new design, using SMT technology

Need professional quality features but can't justify the cost of a commercial FM exciter? The FM25B is the answer! A cut above the rest, the FM25B features a PIC microprocessor for easy frequency programming without the need for look-up tables or complicated formulas! The transmit frequency is easily set using DIP switches; no need for tuning coils or "tweaking" to work with today's 'digital' receivers. Frequency drift is a thing of the past with PLL control making your signal rock solid all the time - just like commercial stations. Kit comes complete with case set, whip antenna, 120 VAC power adapter, 1/8" Stereo to RCA patch cable, and easy assembly instructions - you'll be on the air in just an evening!

FM25B	Professional Synthesized FM Stereo Transmitter Kit	$139.95

Tunable FM Stereo Transmitter

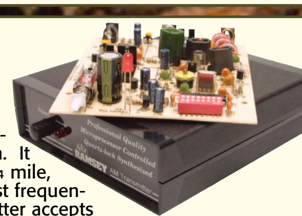


- ✔ Tunable throughout the FM band, 88-108 MHz
- ✔ Settable pre-emphasis 50 or 75 µSec for worldwide operation
- ✔ Line level inputs with RCA connectors

The FM10A has plenty of power and our manual goes into great detail outlining all the aspects of antennas, transmitting range and the FCC rules and regulations. Runs on internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter is also available. Includes matching case!

FM10C	Tunable FM Stereo Transmitter Kit	$44.95
FMAC	110VAC Power Supply for FM10A	$9.95

Professional Synthesized AM Transmitter



- ✔ Fully frequency synthesized, no frequency drift!
- ✔ Ideal for schools
- ✔ Microprocessor controlled

Run your own radio station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area. It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. Broadcast frequency is easily set with dip-switches and is stable without drifting. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!

AM25	Professional Synthesized AM Transmitter Kit	$99.95

Tunable AM Transmitter

- ✔ Tunes the entire 550-1600 KHz AM band
- ✔ 100 mW output, operates on 9-12 VDC
- ✔ Line level input with RCA connector

A great first kit, and a really neat AM transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! One of the most popular kits for schools and scouts! Includes matching case for a finished look!

AM1C	Tunable AM Radio Transmitter Kit	$34.95
AC125	110VAC Power Supply for AM1	$9.95

Mini-Kits... The Building Blocks!

LED Animated Santa

Animated Santa and reindeer display has 126 dazzling colored LEDs! Makes a great holiday sign! Animated motion makes it come alive. Runs on standard 9V battery or external power supply.

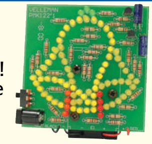
MK116	LED Santa Kit	$19.95

LED Christmas Tree

Electronic Christmas tree features 134 bright colored LEDs in the shape of a tree with 18 random flashing blinking "candles"! Runs on a 9V battery or PS.

MK117	LED Xmas Tree Kit	$17.95

LED Animated Bell



This holiday bell is animated to simulate swinging back and forth! 84 bright colored LEDs will dazzle you with holiday cheer! Includes an on/off switch. Runs on 9V.

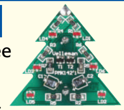
MK122	LED Bell Display Kit	$13.95

3D LED Christmas Tree

Not your average LED display! 4 branch sections give this tree a 3D look! 16 red LEDs light it up with yellow LED's for you to customize your tree! 9V battery base.

MK130	3D LED Tree Kit	$7.95

SMT LED Christmas Tree



Build this subminiature Christmas tree and learn SMT at the same time. Small enough to wear as a badge or pendant! Extra SMT parts are included so you can't go wrong! Runs on Li-Ion cell.

MK142	SMT LED Tree Kit	$8.95

SMT LED Smily Face

This is a great attention grabber and also teaches you the basics of SMT construction! Display your "smily" as a pin or badge! Extra parts included!

MK141	SMT LED Smily Kit	$8.95

LED Traffic Signal

Impress your friends with this neat 4-way traffic signal! Operates just like a standard signal, and features adjustable delay. Red, yellow, and green LEDs are used just like the real thing! Runs on 9V battery.

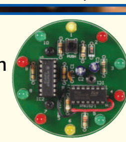
MK131	LED Traffic Signal Kit	$7.95

Stereo Super Ear

The stereo Super Ear features an ultra high gain audio amp with two sensitive microphones! Boosts audio 50 times! Includes volume control. Runs on 3 AAA batteries.

MK136	Stereo Super Ear Kit	$9.95

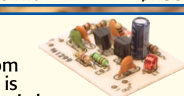
Wheel Of Fortune



Just like the casino game! Just push the button and the LEDs "rotate" and slowly come to a stop, displaying the "winner"! Push it again to start over. Runs on 9V battery.

MK152	Wheel Of Fortune Kit	$7.95

RF Preamplifier



Super broadband preamp from 100 KHz to 1000 MHz! Gain is greater than 20dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7	RF Preamp Kit	$19.95

Light Sensitive Switch

Senses light to turn your device on at night, off at dawn! Provides a NO/NC 5A relay contact. Adjustable delay. Runs on 12VDC.

MK125	Light Sens Switch Kit	$7.95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Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, as well as comments and suggestions.

You can reach me at:
TJBYERS@aol.com

What's Up:

Thermocouples are highlighted this month. I finally answer the OBD question and give you a fresh look at old monitors and slide viewers. Halloween antics (better late than never) and the real answer to IC voltage regulator pinouts.

Homemade Thermocouples

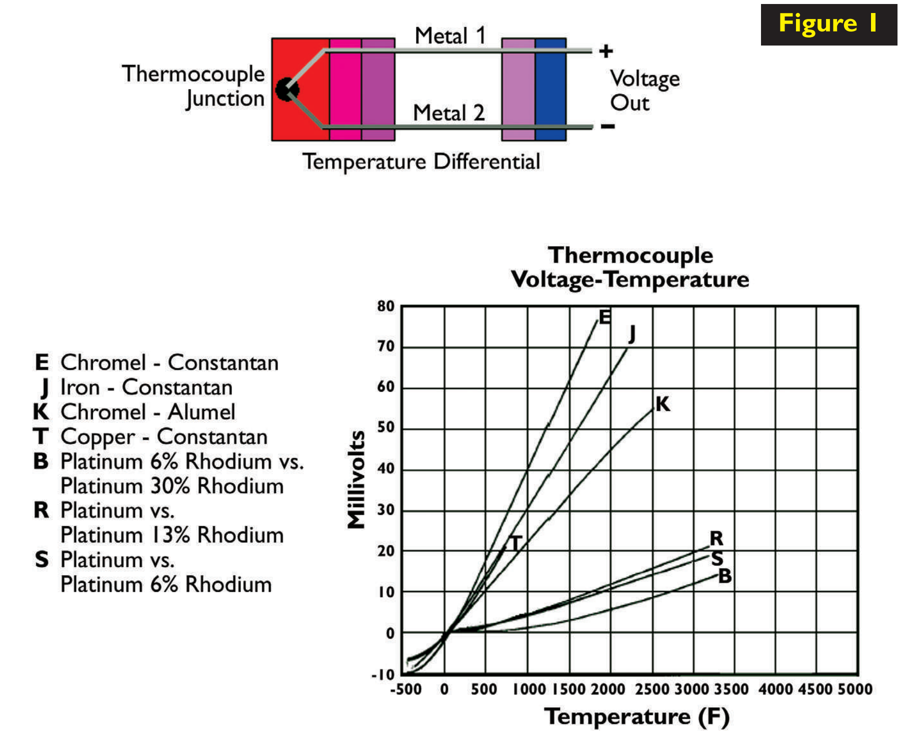
Q. I have need for a lot of thermocouples to monitor hot spots on a racing engine that I'm building. I have a thermocouple bridge with cold junction compensation, but the cost of the thermocouples is getting out of hand; there's a lot of breakage and loss. I've heard that you can make a thermocouple using nothing but thermocouple wire. If this is true, how can I do it?

Mike S.
via Internet

A. Anytime you put two dissimilar metals in contact, you form a thermocouple junction. A thermocouple generates a small voltage — the Seebeck voltage — that's proportional to the temperature difference between the hot and cold junctions. Most people think that the hot junction is the source of the output voltage. This is wrong. The voltage is generated across the length of the wire (Figure 1). If the wire length is at the same temperature, no voltage is generated, hence the cold junction reference voltage.

While it's acceptable to make a thermocouple junction by soldering the two metals together, most thermocouple junctions are welded together to ensure that the sensor isn't limited by the melting point of the solder. Back when I worked for NASA, we had a thermocouple in every nook and cranny of the space craft during functional testing prior to launch. We made lots of thermocouples by hand using a 15 volt power supply and a carbon rod salvaged from a D cell carbon

Figure 1



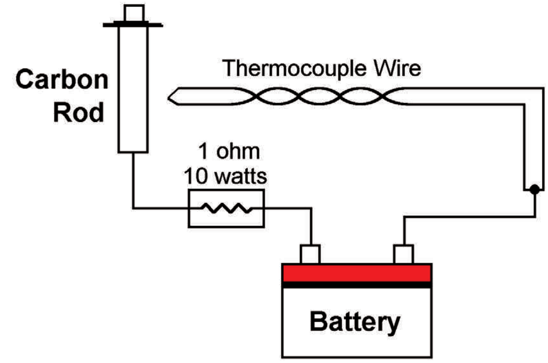


Figure 2 Thermocouple Welder

battery. Since then, I've done the same using a car battery. Unlike the power supply — which was current limited — a ballast resistor has to be inserted in series with the battery (Figure 2).

The size of the resistor depends on the diameter of the thermocouple wire you use. If the current is too large, you'll vaporize the junction rather than weld it. For your application, I'd use 20 AWG (gauge) wire and limit the current to 12 amps using a 1 Ω, 10 watt resistor.

First, obtain a carbon rod by carefully taking apart a carbon — not alkaline — battery. (Ingredients in alkaline batteries are extremely caustic; for safety reasons, do not take one apart!) If you remove the top cap, the rod usually slips out easily with the metal button still intact. Cut the thermocouple wire to just longer than you need, then twist both ends together using pliers. Connect one end of the "cable" to the battery negative and the carbon rod to the positive source. Quickly tap the carbon rod to the thermocouple junction. If you do it properly, a small, round bead will form. If the weld is sputtered, increase the current by using a lower value resistor; if the wire vaporizes, increase the resistance. Cut off the unwelded end and there you have it.

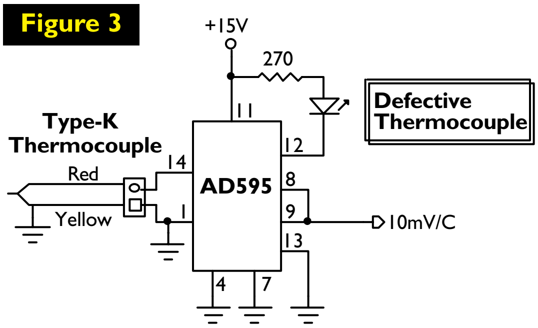
While it's unlikely the small spark will do any UV damage to your eyes, it's better to wear sunglasses to protect them.

BBQ Thermometer

Q. I would like to build a circuit to measure the temperature at the surface of my charcoal grill, which probably means that I need a sensor capable of handling temperatures in excess of 700° F. I assume that means using a thermocouple, but my web searches thus far have failed to provide enough information about how to interface a thermocouple to a microcontroller like a BASIC Stamp or a PIC.

If you could provide a simple circuit for interfacing thermocouples and a source where I could actually

Figure 3



Thermocouple Cold Junction Compensator

purchase one or two of them, I would really appreciate the help.

Ron Hackett
Port Jefferson, NY

A. There is more than one avenue you can take to create what you're trying to build. The fastest is to buy the DS2760 kit from Parallax (888-512-1024; **www.parallax.com**) for $29.95. It contains everything you need — including three thermocouples, the software, and a detailed instruction manual.

If you insist on doing it yourself, you need to begin with a cold-junction thermocouple compensating amplifier. There are a handful available, including the LT1025, AD7708, and MAX6675. My choice is the AD594/AD595 from Analog Digital. In addition to a compensating amp, it includes an open thermocouple alarm and an over/under temp controller with a programmable set point that you can use to control an external heater or fan. The output voltage is 10 mV/°C, where 4.00 volts equals 400°C.

The AD594 uses a Type-J thermocouple with a limit of 750°C (1,380°F) and the AD595 uses a Type-K thermocouple with a 1250°C limit (2,282°F). The Type-K thermocouple is slightly more linear in the range you desire. You can buy affordable thermocouples from Omega Engineering (888-826-6342; **www.omega.com**) or make your own using thermocouple wire (refer back to "Homemade Thermocouples"). When selecting a thermocouple, make sure the covering can withstand your temperatures.

The AD595 thermocouple circuit, shown in Figure 3, uses just two external parts — and they are optional. Everything needed to condition the thermocouple output into an amplified linear voltage is contained inside the AD595. You now have the option of measuring the output voltage directly with a DMM or inputting the voltage to a microprocessor via an analog-to-digital converter (ADC). Remember, the output voltage is proportional to a Centigrade temperature, so one of the jobs the PIC can do is convert that value to Fahrenheit.

The OBD Party

Q. Is there some kind of interface I can build to read the computer signals from a car's electrical system, such as my Dodge and Ford? Do I need software?

Anonymous
via Internet

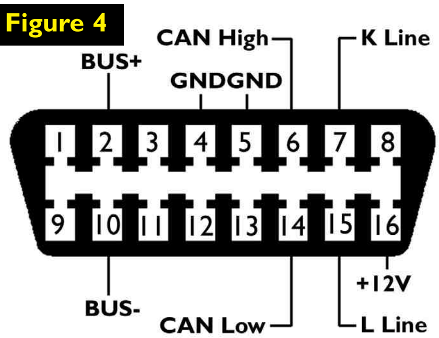
A. Since 1996, all passenger cars, light-duty trucks, and medium-duty vehicles are required to be equipped with OBD II systems — an interface module that outputs signals from the vehicle's onboard computer. While the hardware was defined (Figure 4), the software protocol was left up to the individual car maker. Not surprisingly, three protocols (from the Big Three) resulted, as shown below.

OBD II (PWM) — Ford
OBD II (VPW) — GM
OBD II (ISO) — Chrysler, Asia, Europe

Also not surprisingly, they have nothing in common. Which means the data coming from your Ford's OBD II module can't be read by a Dodge reader. Moreover, just because the connector was defined, not all the signal lines have to be used. For example, the L Line is used in a small number of models, but has gone largely ignored with the K Line taking center stage. Then, there is the new CAN interface with its two pins, which becomes law in 2008, but is sparsely implemented today.

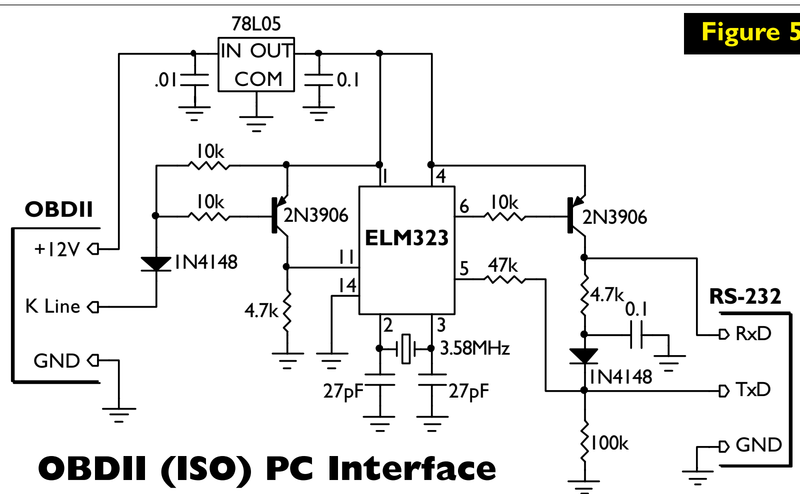
This means you need three interface cables, not one. (Why can't US

Figure 4



OBD II Connector

Figure 5



OBDII (ISO) PC Interface

makers ever agree on one standard?) Fortunately, ELM Electronics (**www.elmelectronics.com**) sells three OBD II interface ICs — one for each protocol.

Figure 5 shows a typical ISO interface using the ELM323 chip. The ELM chips are based on a Microchip 12C5xx microcontroller, which contains the language translator to simplify writing the software.

Yes, you need software so that your PC can read the OBD II. Unfortunately, that's harder to find than the hardware. Most of the sites for free software have disappeared for various reasons.

One that seems to be solid is ScanTool.net(**http://scantool.net/software/scantool.net**), but it's machine specific so I can't say it will work for you. If you want to try your hand at writing your own software, the following websites are required reading.

OBD II codes
www.obdii.com/codes.html

Software guidelines
www.obddiagnostics.com/obdinfo/info.html

Heart Rate Monitor

Q. If you have addressed this particular type circuit, I missed it. I spent yesterday trying to locate a heart rate monitor I could buy that didn't cost the equivalent of my first born. Is it possible to design and build some sort of circuit that I can attach to my chest or arm or hand and read my changing heart rate?

Kim D. Port
via Internet

A. Before former President Bill Clinton went under the knife, I would have given you a circuit that involved op-amps, an ADC, and some kind of display interface. At the least, a PIC chip with external baggage. (In fact, it was under consideration.) Today, you can buy a "Cardio Digital Heart Rate Monitor" from Target online (**www.target.com/gp/detail.html/60244635744965420?asin=B00006WNS1**) for just $27.99, watch included. Target isn't the only source. Check out your local pharmacy and expect prices to drop as we become more heart aware.

Old Monitor, New Life

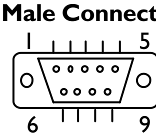
Q. I have an old computer monitor that I would like to use to display an analog TV signal and play the audio. The cable has an RS-232 connector. I need the pinout for the RS-232 to connect the video and audio signals.

E. D. Kiehm
Orlando, FL

A. Without a model number for the monitor, I can only make an educated guess. Back in the days of old, there were two monitors that used an RS-232 cable. The most popular had a nine-pin connector.

Figure 6

DB-9
Male Connector



9-Pin VGA

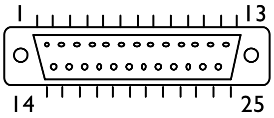
Pin	Function
1	Red video
2	Green video
3	Blue video
4	H Sync
5	V Sync
6	R Gnd
7	G Gnd
8	B GND
9	Sync Gnd

Sony CPD-1302

Pin	Function
1	GND
2	NC
3	Red video
4	Green video
5	Blue video
6	NC
7	NC
8	H Sync
9	V Sync

Figure 7

DB-25
Male Connector



AT&T PC6300

Pin	Function	Pin	Function
1	H Sync	10	ID1
2	ID0	11	Mode 0
3	V Sync	12	NC
4	Red video	13	Degauss
5	Green video	14-21	GND
6	Blue video	22	NC
7	?	23	NC
8	NC	24	+15V
9	NC	25	+15V

For color ID0 is grounded and ID1 open
For monochrome ID0 and ID1 are open

NEC — along with a handful of others — used this format for a short time, with NEC leading the way and changing pinout midship. The other was the AT&T PC6300, which used a 25-pin connector. Neither had sound capabilities. Find both monitor pinouts in Figures 6 and 7. Most of these monitors were multisync (i.e., they can sync to different scan rates), so your TV video has a good chance of working with it.

Slide Viewer

Q. I am interested in making a 35 mm color negative viewer using one of the inexpensive CCD cameras now available. I would, of course, like the picture to show true colors and not the negative colors of yellow, magenta, and cyan. I think I only need to invert the video and not the sync portion of the NTSC signal. Could you suggest a suitable circuit?

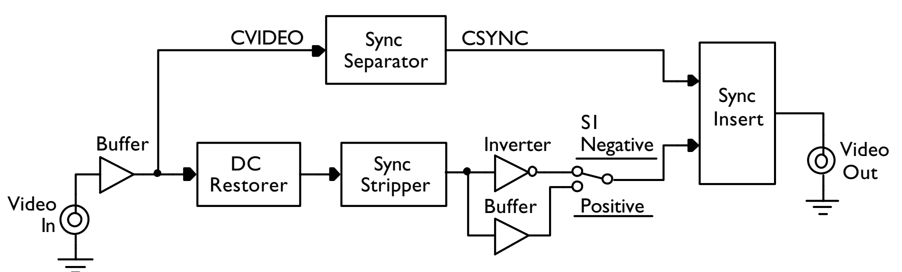
David Parkinson
Mill Valley, CA

A. You are correct in that inverting the entire composite video signal would scramble the picture and make it unviewable. This means you have to strip out the sync signal, invert the video, and recombine them. This is beyond the scope of this column, but I can point you in the right direction. Refer to Figure 8.

The Video In is first buffered to provide impedance matching and reduce loading on the source. The composite signal is now split, with the bottom path stripping the signal of sync pulses and the top path stripping it of video. At this point, you have the option of displaying the image in a positive or negative image using S1 by either having the video go through an inverter or a buffer amplifier.

While a positive image could be had by bypassing the inverter, the buffer is included to prevent color shift caused by differing signal delays when switching between negative and positive screens. The sync and video are finally recombined and output to the video monitor as a composite signal. You can find the circuits you need in application notes AN9514 and AN9752 from Intersil (**www.intersil.com**) and the LM1881 datasheet from National (**www.national.com**).

If you have a PC with a scanner, you can use an image editor like Paint Shop Pro or PCFoto (see Cool Websites!) for converting your scanned color negatives to positives for viewing on a PC monitor.



Video Color Inverter

Figure 8

CHU Receiver

Q. I live near the East Coast of the US and CHU-Ottawa is often easier to receive than WWV-Ft. Collins. I have visited the Canadian website that describes the CHU Broadcast Codes (**http://inms-ienm.nrccnrc.gc.ca/time_services/chu.html**), which seem simple enough, but I would like help (websites) tracking down information on any receivers or combinations of receivers-modems-firmware computers that can use the time code in a manner similar to the Heathkit Most Accurate Clock.

I had in mind either published articles describing techniques to build such clocks or, perhaps, a kit produced for the Canadian market that would be within my price range. If you know of any websites that could get me started on my search, I'd very much appreciate it.

Joseph F. Richmond
via Internet

A. While there are no known commercial CHU receivers, a simple — but effective — receiver can be constructed from an ordinary shortwave receiver and Bell 103 compatible, 300 BPS modem. Unfortunately, the Pulse-Per-Second (PPS) Signal Interfacing page — which described a homemade CHU receiver — has been disconnected and I can't find a substitute. Maybe one of our readers still has a file of the driver7 receiver and is willing to share it with you. In the meanwhile, the following website has enough information to get you started.

www.eecis.udel.edu/~mills/ntp/html/drivers/driver7.html

Scream Power

Q. One of my hobbies involves creating outdoor Halloween displays. One favorite trick is to take a prop that can be purchased commercially and "hack" it to actuate a jaw motion, blinking and/or illuminated eyes, and reproduce the sound through an internal speaker. Home haunters typically connect two of these props to the audio output of a CD player, running one channel's audio to one prop and the other channel's audio to the other. That way, the appearance of a conversation can be created. If one has access to more expensive multi-track equipment, more devices can be connected.

My idea would allow me to connect more than just two props to a single CD player's audio source. The control audio would consist of a series of individual tones, one tone for each prop. I assume that I'd need a series of fairly narrow band-pass filters to sort out the tones from the functions. That's where I get stuck. Do you have any ideas for filtering out the tones that can be translated into a relay or solenoid action?

Jon Westcot
via Internet

A. What a great idea! What I recommend is a DTMF tone that can be easily decoded using a single IC like the MT8870 (available from Futurlec; **www.futurlec.com**). What is DTMF? It's those tones you hear when dialing your cell phone. Each number is made up of two tones (see Table 1). You can use these tones to drive up to 16 props and still have the other channel free for voice.

Figure 9 shows a circuit for a simple four channel decoder. You have to provide the Audio In interface to your CD or other device — like the earphone output of a Walkman-type amp. You can control up to 16 props with this circuit using NAND logic. Need a DTMF tone generator for recording your sequence? Try a land line telephone.

Table 1. MT8870 DTMF decoder.

Key	Freq 1	Freq 2	Q4	Q3	Q2	Q1
1	697	1209	0	0	0	1
2	697	1336	0	0	1	0
3	697	1477	0	0	1	1
4	770	1209	0	1	0	0
5	770	1336	0	1	0	1
6	770	1477	0	1	1	0
7	852	1209	0	1	1	1
8	852	1336	1	0	0	0
9	852	1447	1	0	0	1
0	852	1209	1	0	1	0
*	941	1336	1	0	1	1
#	941	1477	1	1	0	0
A	941	1633	1	1	0	1
B	770	1633	1	1	1	0
C	852	1633	1	1	1	1
D	941	1633	0	0	0	0

MAILBAG

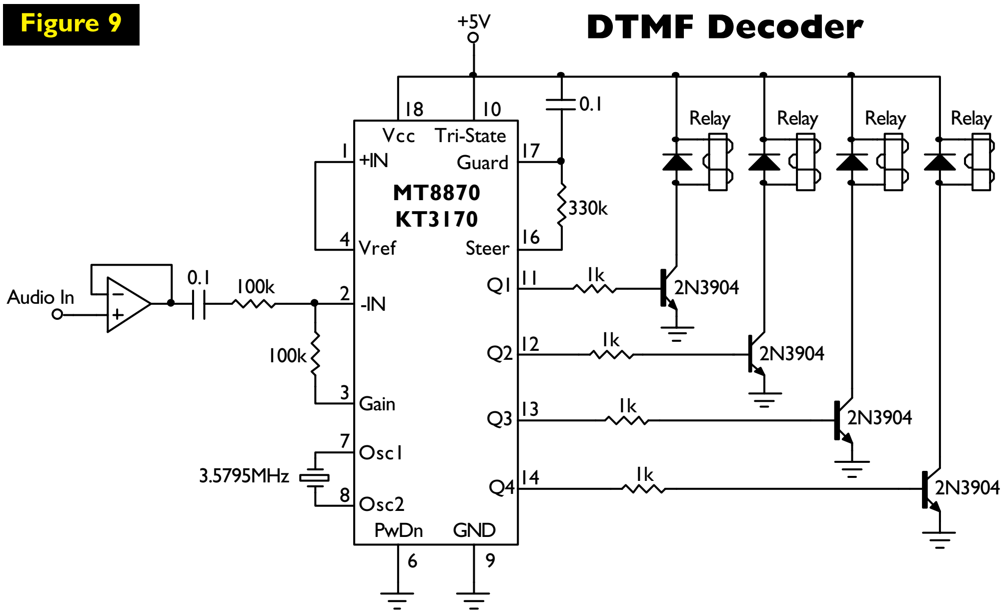
Dear TJ,

I saw your answer in the July 2004 issue to someone who asked why voltage regulator pinouts varied. I work in the IC industry and have the definitive explanation for the 7805 versus 7905 difference.

These voltage regulators are designed in a process that uses a P-type substrate. For isolation of the components on the chip, the P-substrate must be at the most negative voltage (so all the PN junctions of the diffusions into the substrate are reverse biased). When a chip is mounted in its package, it is mounted to the heatsink tab of the TO-220 package or to the base of the TO-3 using conductive epoxy. This means that the substrate of the chip is electrically connected to these chunks of metal.

Since the chip substrate must be at the most negative

Figure 9 **DTMF Decoder**



potential and it is connected to the tab, the tab of the TO-220 must also be at the most negative potential. For a positive voltage regulator, the most negative potential is ground; for a negative voltage regulator, it is the input voltage. That's the way it goes. Negative dominates.

Steve
via Internet

Dear TJ,

I had some unexpected days off due to Hurricane Ivan and used part of the time to build your lightning detector from page 32 of the September 2004 issue. Ironically, I am still waiting for a thunderstorm in which to test it, but a long antenna does pick up appliances turning on and off.

I have a question about the tuned circuit. The inductance values look low for 300 kHz. When I plugged them into a calculator, I get a resonant frequency of 15 MHz. It seems that 10 mH and 1 mH would be a lot closer. Am I missing something?

Thomas L Keister Jr., M.D.
via Internet

Response: *Oops! My schematic capture program defaults to µH and I forgot to change it to mH. Good catch! — TJ*

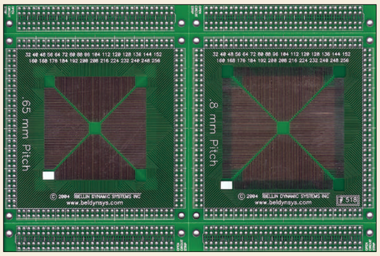
Cool Websites!

I see myself as savvy enough to figure out most acronyms, but IIRC had me. If you're at a loss, go to the Acronym Finder site.
http://www.acronymfinder.com/afquery.asp?String=exact&Acronym=iirc&Find=Find

What time is it? Here's a nifty site with instant access to the time every place in the world.
www.timeticker.com/

PCFoto is a free software program for converting your scanned color negatives to positive photos right on the desktop.
www.softforall.com/Multimedia/ImageEditing/PCFoto07050143.htm

SMT UNIVERSAL QUAD ADAPTERS



Bellin Dynamic Systems, Inc., has announced the latest Snap-Apart™ adapter board — the P518. The P518 is a Universal Quad Adapter that will work with most SMT Quad ICs. It is designed to adapt Quad ICs with 32–256 leads on .65 mm or .8 mm spacing. Each adapter takes SMT Quad chips and breaks the leads out into dual row, .100" header pins. The kit holds one Snap-Apart board with two adapters and eight 80-pin, .100" header strips. The P518 is a quick and economical solution to Quad SMT prototyping. Pictures, product information, and printable data fit check sheets are available at the Bellin website.

Bellin Dynamic Systems is a provider of rapid prototyping tools for engineering development. For more information on the P518 Universal Quad Adapter and other Snap-Apart adapter boards, stop by their website.

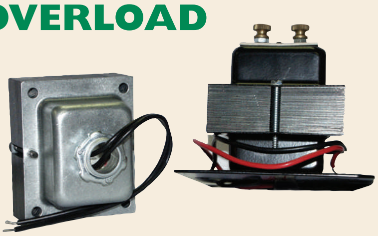
The P518 is currently available for $59.95 each.

For more information, contact:

BELLIN DYNAMIC SYSTEMS, INC.
211 S. State College Blvd. #319
Anaheim, CA 92806
714-630-8024 Fax: **714-630-8025**
Email: **jsohn@beldynsys.com**
Web: **www.beldynsys.com**

Circle #38 on the Reader Service Card.

NEW LIGHTING CONTROL TRANSFORMERS FEATURE AUTO-RESET OVERLOAD PROTECTION



Foster Transformer has introduced a new line of Lighting Control transformers that automatically reset after experiencing an overload situation. They are ideal for lighting control panels or wherever Class 2 protection is required to actuate banks of relays, contactors, solenoid valves, pilot lamps, or similar loads.

Various UL and C-UL listed models are available, each with 40 VA continuous and 75 VA intermittent capacity ratings for 50/60 Hz service. Input voltages available include 115 V, 220 V, 240 V, 277 V, 347 V, and 115/277 V or 115/240/277, all with 24 V output. Each size/model includes UL Recognized Class 130 (B) insulation. IEC, EN, and CE compliant designs are available. Three standard styles encompass a variety of mounting and wiring configurations — alternate versions can be configured to meet specific customer requirements.

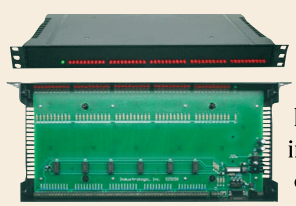
Foster Transformer has been making electronic transformers, power supplies, and electromagnetic components for nearly 70 years. Their corporate headquarters, engineering lab, and primary manufacturing facility are located in Cincinnati, OH. The ability to manufacture their own tooling, fixtures, and unique production machinery allows Foster to provide quick turnaround, start-up, and support for low to mid volumes from the Cincinnati plant. Additional manufacturing capacity is provided by plants in Seymour, IN and Dongguan City, China.

For more information, contact:

FOSTER TRANSFORMER
3820 Colerain Ave.
Cincinnati, OH 45223
Tel: **800-963-9799**
Email: **info@foster-transformer.com**

Circle #44 on the Reader Service Card.

SI5150 PROGRAMMABLE SWITCH INPUT CONTROLLER



The Industrologic SI5150 is a microcontroller-based, single board computer designed to be a complete industrial switch input controller assembly that is easy to program and connect to external signals. It includes both a large bank of 50 contact closure inputs, but a logic level input/output signal.

The SI5150 printed circuit board is designed to mount directly into the Bud Industries PRM-14460 ABS rack/table mount enclosure. This enclosure can be quickly converted from rack mount to table top use and includes all required brackets for both configurations.

The board can be programmed as a standalone controller using its onboard Tiny Machine Basic programming language or it can be used as an RS-232 serial data acquisition board. The SI5150 is based on the Atmel AT89C4051 microcontroller chip with EEPROM program memory and can be reprogrammed using any number of software development tools and device programmers available for Atmel microcontrollers.

Communication with the SI5150 is accomplished via a serial RS-232 port with true RS-232 interface and a DB9F connector that matches a PC compatible serial port pinout.

Convenient screw terminal block connections are used for all signals and power, which include 50 contact closure inputs and one logic level signal that is usable as an input or output. The logic level signal is connected to

a microcontroller interrupt signal to enable the board to capture short events or to count pulses.

The SI5150 package is shipped complete with all items necessary to immediately begin application development — including a serial port cable for connection to a PC compatible computer, a wall block power supply, host computer software and programming examples, and hardware and software reference manuals.

For more information, contact:

INDUSTROLOGIC, INC.
3201 Highgate
St. Charles, MO 63301
Tel: **636-723-4000** or **800-435-1975**
Web: **www.industrologic.com**

Circle #29 on the Reader Service Card.

STINGRAY DUAL-CHANNEL USB SCOPE ADAPTER "FISHES" FOR SIGNALS

Stingray™ is a tiny, new dual-channel PC Digital Oscilloscope adapter that samples at 1 Ms/sec with 12 bit precision and costs less than $200.00.

Sized at only 3.5" x 4.5" x 1.2" and weighing less than 5 oz, Stingray is powered solely from a USB port. Stingray combines the functions of an oscilloscope, data logger, spectrum analyzer, volt meter, frequency meter, and signal generator in a single device. It features simultaneous 12 bit sampling on both channels, a native sampling rate of 1 Ms/s (20 Ms/s for repetitive signals), and 32 kbytes of sample buffer with sophisticated hardware triggering, including delayed time base and pulse width. Additionally, Stingray has a third channel that can be configured as a waveform generator output or an external trigger input.

Stingray comes complete with EasyScope II oscilloscope software for signal display and EasyLogger software which gives continuous PC data logging capabilities. Windows DLLs are supplied to allow third party applications to easily interface to Stingray. Example code is provided in several popular programming languages, including LabView. Windows CE and Linux drivers are also available on request.

Using standard scope probes, the input voltage range is an amazing ±50 V, with voltage scalable from 10 mV/div to 2 V/div and time-base adjustable from 50 µS/div to 50 mS/div using the EasyScope II software supplied.

Stingray makes a great addition to any engineer's toolbox or an economical device for education and testing and is very easy to use and install. Using USB has many advantages over legacy printer and serial ports. It fully supports plug-and-play, so Stingray is immediately recognized and configured on plug-in. USB is also fast and allows for a cable length of up to 15 feet between the instrument and a PC.

Stingray (complete with software) is priced at only $199.00 from Saelig Company, Inc.

For more information, contact:

SAELIG CO., INC.
1160-D2 Pittsford-Victor Rd.
Pittsford, NY 14534
585-385-1750 Fax: **585-385-1768**
Email: **info@saelig.com**
Web: **www.saelig.com**

Circle #113 on the Reader Service Card.

MICRO64 EMBEDDED MICROCONTROLLER MODULES

Micromint, Inc., has introduced the Micro64 Embedded Microcontroller Modules aimed at industrial control applications. The module uses an Atmel mega64 AVR controller. These modules can be programmed in C, Basic, or assembly language. A development package consists of a development board with power supply, a Micro64 module, a programming cable, and a free, limited version of CodeVision AVR C compiler.

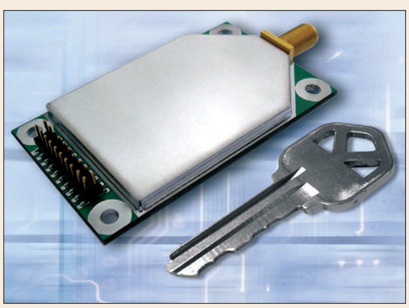
The Micro64 is an encapsulated module that is 1.5" x 2.1" x 0.5". The Micro64 features 64K of program space, 2K of EEPROM data space, and 36K of SRAM. Other features include 29 digital I/O, eight channels of 10 bit ADC, a real time clock calendar with alarm function, two USARTs, six PWM channels, an SPI bus, an I^2C bus, and an optional two channel, 12 bit ADC. The Micro64 can be a hardware replacement for Micromint's Domino 2. Similar to Micromint's Domino 2 Controller, there are literally thousands of applications for the Micro64 Embedded Controller Module. A Micro128 version is due out soon and will use the mega128 AVR controller.

For more information, contact:

MICROMINT, INC.
115 Timberlachen Cir.
Lake Mary, FL 32746
Tel: **407-262-0066**
Email: **sales@micromint.com**
Web: **www.micromint.com**

Circle #127 on the Reader Service Card.

SECURE 1 WATT WIRELESS



The 9XTend wireless transceiver provides OEMs the highest encryption standard available (256 bit AES encryption), the highest power output allowed by the FCC (1 mW-1 W, software selectable), the longest low cost transmission range (up to 3,000 ft in indoor/urban environments, up to 40 miles line-of-sight), the highest 900 MHz data throughput (up to 115 kbps sustainable RF data rate, up to 230 kbps interface data rate), and the industry's smallest full 1 watt form factor. The 9XTend is ideal for secure, critical, and long range applications, including homeland security, remote monitoring, building automation systems, automated teller machines, point-of-sale terminals, and keyless/remote access systems, among others. Development kits and production units are available now. Also available is an enclosed, plug-and-play RS-232/485 radio modem.

For more information, contact:

MAXSTREAM, INC.
355 S. 520 W. #180
Lindon, UT 84042
801-765-9885 Fax: **801-765-9895**
Email: **9XTend@maxstream.com**
Web: **www.maxstream.com**

Circle #140 on the Reader Service Card.

STATE OF THE ART DIGITAL RECORDING AT ITS VERY BEST

The DDR-3256 is a tiny, but versatile unit that offers an incredible 90 hour recording capacity with 256 Mb internal memory, excellent sound quality, and features found only in the Diasonic DDR-3000 series.

For voice recording, the DDR-3256 offers a high quality built-in microphone, as well as an included "tie clip" type microphone. By switching on the ARS (automatic recording system), a voice activation and automatic gain control circuit takes over and only records when sound is present, eliminating blank spaces in recording.

Time/Date Stamped Automatic Telephone Recording

For telephone recording, simply connect the included analog telephone recording control module to your single line phone jack and all your phone calls — from any extension on line — will be automatically recorded with crystal clarity. Recording will begin when a call is started and stop when the conversation is complete. The AC adaptor offers unlimited power for telephone recording. Due to the exclusive "AUTO FILE ADVANCE" feature, each call will be indexed with complete time/date stamp information. Also included is a hands-free cell phone recording adaptor that allows easy, hands-free recording of your important cell phone calls.

High Speed USB Upload

All of your recordings can be quickly uploaded via a USB port to your PC at a super fast 1000X speed. (Ninety hours of recording only takes about six minutes to upload.) You may elect to simply play back your recordings on the

(continued on Page 73)

Electronics Showcase

Reader Feedback

(Continued from Page 6)

Dear Nuts and Volts:

I love your magazine, the content, its presentation, and the editorials. I even like the ads. I can't think of another magazine I'd say THAT about.

My favorite part is Gerard Fonte's "In The Trenches." It's to the point, insightful, and often very funny. He outdid himself with the October 2004 column — "You Might Be An Engineer." It completely cracked me up.

Bob Colwell
via Internet

Dear Nuts & Volts:

I just wanted to pass along an FYI to Walter Krawec about his article in the October issue. There is a free Windows IDE/Compiler for PALM at PalmSource. It is called Eclipse and it uses the GNU C compiler from Linux (through Cygwin). It works like a dream and costs nothing. You can even debug your application on the Palm Emulator under Windows (very cool). It is, however, a 196 Mb download. It can be found at **www.palmos.com/dev/dl/dl_tools/dl_pods/**

John Voltz
via Internet

THE OWNERSHIP, MANAGEMENT, AND CIRCULATION STATEMENT OF NUTS & VOLTS MAGAZINE, published monthly at 430 Princeland Ct., Corona, CA 92879. Subscription price is $24.95. The names and addresses of the Publisher, Editor, and Managing Editor are: Publisher, Jack Lemieux, 430 Princeland Ct., Corona, CA. 92879; Editor, Larry Lemieux, 430 Princeland Ct., Corona, CA 92879; Managing Editor, Dan Danknick, 430 Princeland Ct., Corona, CA 92879. The owner is T & L Publications, Inc. Corona, CA 92879. The names and addresses of stockholders holding one percent or more of the total amount of stock are: Jack Lemieux, 430 Princeland Ct., Corona, CA 92879; Larry Lemieux, 430 Princeland Ct., Corona, CA 92879; Audrey Lemieux, 430 Princeland Ct., Corona, CA 92879. The average number of copies of each issue during the proceeding twelve months is: A) Total number of copies printed (net press run); 53,291 B) Paid/Requested Circulation (1) Mail subscriptions: 39,807; (3) Sales through dealers and carriers, street vendor, and counter sales: 7,414; C) Total paid circulation: 47,221; E) Free distribution outside the mail (carrier or other means): 772; F) Total free distribution:772; G) Total Distribution: 47,993; H) Copies not distributed: (1) Office use, leftover, estimated newsstand returns, spoiled after printing: 5,298; I) Total: 53,291. Percentage paid and/or requested circulation: 98.39 %. Actual number of copies of the single issue published nearest the filing date is September 2004, Issue #9; A) Total number of copies printed (net press run) 49,238; B) Paid/Requested Circulation (1) Mail subscriptions: 36,839; (3) Sales through dealers and carriers, street vendors, and counter sales 6,462; (C) Total paid circulation: 43,301; E) Free distribution outside the mail (carrier or other means): 511; (G) Total Distribution: 43,812; (H) Copies not distributed: (1) Office use, leftover, estimated newsstand returns, spoiled after printing: 5,426; (I) Total: 49,238. Percent paid and/or requested circulation: 98.83%. I certify that these statements are correct and complete. Mary Descaro, Circulation Director.

Geek Stylin'

Sure, I know — they've been reinvented as *technogensia*, like Trekkies are now called *Trekkers* — but you can't ignore their persistent love for gadgetry. Well, a quick look at a modern peace officer teaches you that only so much stuff will fit on a belt. What in the world is an early adopter to do? Why, buy a SCOTTeVEST!

Originating from the company of the same name, the model "Version Three.0 Cotton" is, "made to be lived in," according to company founder Scott E. Jordan. Now, the SeV sports 32 hidden, ergonomically designed pockets and compartments, a silky lining, and mesh interior. I don't know how warm it will keep you this winter, but the PAN (Personal Area Network) enabled facet should let you rig a couple of Peltier heat exchangers to some NiCad packs while still powering your iPod Mini, Garmin GPS, and SEP (Someone Else's Problem) field generator.

Oh, if you're donning this in a mostly sunny locale, pony up the extra $225.00 and fill two of the back pockets with solar panels — I kid you not! The panels are buffered by a small battery pack and can be used with any small electronic gadget that allows recharging through a USB connection.

Of course, getting through airport security with a fully decked-out SeV could be interesting ...

For more information, visit the SeV website at **www.scottevest.com**

The Time Is 10:23 and 47W

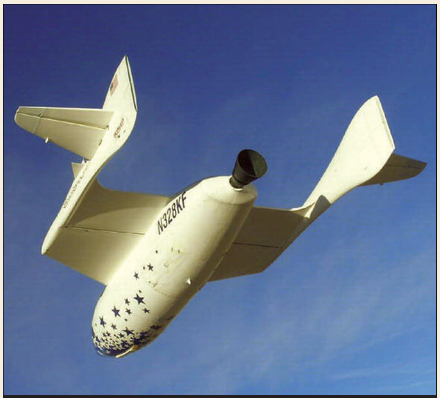
After you order your SeV, you will want to check out the nifty

watches and desk clocks that TechNote Time is selling.

On the face, each displays Ohm's Law, AC and DC power equations, and even resistor band color codes. One of these would make a perfect Christmas gift for the electronic hobbyist in your family (along with a one year subscription to *Nuts & Volts*). You know, I could have really used one of these in high school.

Visit **www.technotetime.com** for ordering information.

Burt Rutan Pulls It Off!



Courtesy of Scaled Composites, LLC.

On Monday, October 4, 2004, Burt Rutan's commercially built SpaceShipOne made aviation history as the first non-governmental craft to return to space within a two week span.

Dropped from a "mother ship" airplane, the space ship exceeded an altitude of 62 miles (100 km) under the power of a hybrid rocket engine. Note that this is only the second known supersonic craft that is manually controlled — no small feat for the pilot!

Even more amazing is that Rutan's company — Scaled Composites — does not use wind tunnel testing, but opts for designs stemming from computation fluid dynamic testing on high powered computers.

A very nice result of this achievement was that Rutan took home the ANSARI X-PRIZE, which includes a $10 million payout for kick-starting commercial space exploration.

There is no question that engineering like this forms the backbone of intellectual and scientific progress in the US — plus, it excites students about staying in the hard sciences.

If you know of a school science class that will be studying space or aeronautics, visit **www.scaled.com** and buy one of their neat lithographs showing how the rocket works.

Who knows, you might spawn the next Burt Rutan!

AM Radio Tx

Use Your Boombox as a PA System

Have you ever been at a meeting where you wanted to make your voice heard? Renting a small public address system is a bit expensive, but you could really use the voice-boosting ability of a modern day "Mr. Microphone." My project shows you how to build such a device, while teaching you a bit about the construction and operation of an AM transmitter.

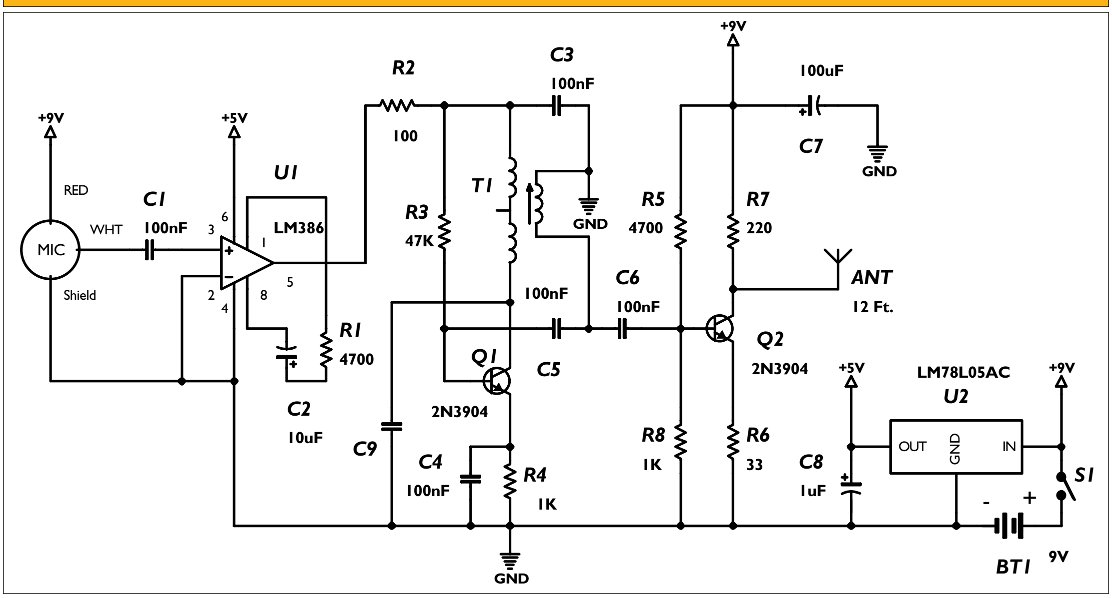
Figure 1 is a schematic for an AM radio public address system transmitter. The circuit is basically a low power AM transmitter. Its antenna is placed near a boombox that is set in the AM frequency band. Amplification of the audio can be set by the volume control on the receiver. The circuit is composed of a modulator, oscillator, and amplifier. U1 is used as a modulator. A microphone is connected to the non-inverting input of U1. U1's gain is 30000/(R1//1350+150). The "//" means "in parallel with." R1//1350=(R1*1350)/(R1+1350). For R1=4700 Ω, the gain is 28. The output of the LM386 amplitude modulates the oscillator formed by Q1, T1, and C9. Q1 is a transformer coupled oscillator.

The secondary winding of T1 is 180° out of phase with the output of Q1. C5 provides AC coupling from this winding to the base of Q1. Transistor Q1 provides another 180° of phase shift necessary for oscillation. The oscillation frequency is determined by C9, the inductance of T1's primary winding, and stray capacitance. The inductance of T1's primary coil is variable from 230 µH to 580 µH. Q2 is an amplifier which drives the antenna. The amplifier input is capacitively coupled to the secondary of T1 by C6. The antenna is connected to the collector of Q2. C3, C7, and C8 are bypass capacitors used to ensure noise-free power to the circuit. U2 is a 5 V regulator that powers U1. This keeps the output of U1 between 0 and 5 VDC. Because U1's output modulates oscillator Q1, the oscillator voltage does not depend on changes in the battery voltage.

Construction

You may download the 2" square PCB image from the *Nuts & Volts* website at **www.nutsvolts.com** along with a component placement diagram. Part references are given in the parts list. First, install the eight-pin socket for U1. Then, mount resistors R1-R8. Solder the transformer T1 to the PCB. Next, install Q1, Q2, U2, and the capacitors (except for C9). Attach the microphone to the pads

Figure 1. Schematic of an AM radio public address circuit.



This Month's Projects

The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

marked "RED," "SHLD," and "WHT" (refer to Figure 2). Solder the black wire of the 9 V battery snap to the "GND" pad on the PCB. Next, attach the red wire from the battery connector to one side of an SPST switch and attach another wire from the other terminal of the switch to the "+9 V" pad on the PCB. Finally, solder the 12 ft antenna wire to the circuit board pad marked "ANT."

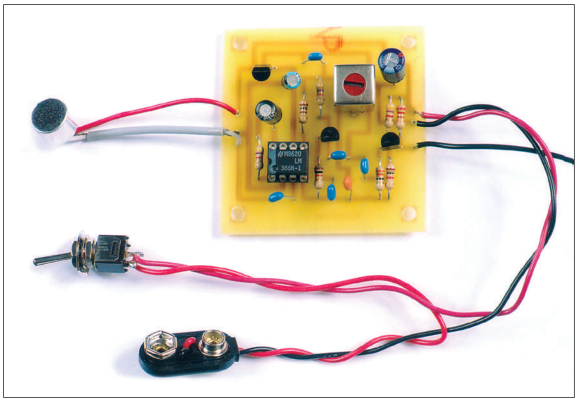


Figure 2. The assembled unit.

Use

Transformer T1 provides limited frequency adjustment. It is not possible to tune the entire AM spectrum with this part. Instead, the AM band is broken into three tuning ranges, each with a corresponding capacitor (C9). Adjust your AM radio to a quiet spot on the dial between 550 kHz and 1.5 MHz. C9 must be chosen so that this frequency is within one of the three transmitter output frequency ranges.

The tuning ranges for a given C9 were measured as follows:

C9	Frequency Range
150 pF	550 kHz-795 kHz
68 pF	714 kHz-1.1 MHz
33 pF	946 kHz-1.5 MHz

For example, if the desired output frequency is 880 kHz, choose a 68 pF capicitor. The tolerance of C9 may result in slightly different carrier frequency ranges. Also, notice that the frequency ranges overlap. After installing the appropriate capacitor for C9, connect a battery and turn the unit on. Turn the slug in T1 with a tuning tool to obtain the desired output frequency. This measurement can be taken with a frequency counter connected between the antenna and ground. Another way to set the output frequency is:

- Tune the AM radio to the desired frequency.
- Place the microphone in front of the boombox speaker.
- Set the AM radio to maximum volume.
- Turn the slug in T1 until feedback is heard.

To eliminate feedback during actual use, keep the microphone behind the boombox speakers. If the receiver and transmitter are both in a small room, feedback is inevitable. Another way to reduce feedback is to lower the volume on the AM radio receiver. A more permanent solution is to reduce the gain of amplifier U1 by increasing or eliminating R1. (Note that, when R1 is not installed, the gain is 20.) Remember, the antenna must be in close proximity to the boombox. I recommend attaching the end of the antenna wire to the AM radio with tape.

Have fun building and operating your boombox public address system. **NV**

Parts List

Designation	Part Description
R1,R5	4,700 Ω 5% 1/4 W
R2	100 Ω 5% 1/4W
R3	47K Ω 5% 1/4 W
R4,R8	1K Ω 5% 1/4 W
R6	33 Ω 5% 1/4 W
R7	220 Ω 5% 1/4 W
C1,C3-C6,	100 nF 20%
C2	10 µF 20%
C7	100 µF 20%
C8	1 µF 20%
C9	See text
Q1,Q2	2N3904 NPN transistor
U1	LM386 audio amp
U2	LM78L05 regulator
T1	Transformer (Mouser 42IF100)
S1	SPST switch
BT1	9 V battery
ANT	12 ft 22 gauge wire
MIC	Condenser mic (RadioShack 270-0092)

by Michael Gardi

An Automatic Audio/Video Switch

A Nice Accessory for Your Home A/V System

I was pretty satisfied with my home entertainment setup. The TV was connected to a cable box, VCR, and a DVD player through a RadioShack (**www.radioshack.com**) four-way audio/video selector (model 15-1976). This particular unit is a push button model, which is both inexpensive and reliable. Having to manually switch inputs didn't seem to be much of a hassle to me, since — for the most part — you had to get up to insert a tape or DVD, anyway.

New Kid on the Block

A few months ago, I purchased a MediaPlayer from PRISMIQ, Inc. (**www.prismiq.com**). PRISMIQ describes the MediaPlayer as an "entertainment gateway." It connects to your cabled or wireless home network and allows you to stream video, audio, and image files from your PC to your TV.

Also, the MediaPlayer lets you view personal news and information, listen to Internet radio, and — with the optional wireless keyboard — surf the web and Instant Message with your friends.

So, in addition to watching recorded programs or listening to your MP3 collection, the MediaPlayer lends itself to the "quick switch" to check the local weather forecast or get a get a stock quote. Without having any media to insert, it became increasingly annoying to have to get up just to switch to the MediaPlayer input. In the spirit of a true couch potato, I realized that something had to be done.

Figure 1. The completed unit, seen from the front.

Which Switch?

When I started looking for a replacement switch, I found there are a number of alternatives. Some models come with their own remote control, which is used to select inputs. They are not very expensive, but I already had five remotes in my family room and I was not interested in having another one.

Other A/V switches have a remote control "learning mode." You can train them to recognize the "power on" button for a particular device and switch to that input when detected. I actually tried one of these briefly, but was not very happy with it. My main beef was that I was constantly turning components off, then on again to get it to switch to that input.

The most promising alternatives to me were the automatic switches. These devices would automatically select the input with a "live" video signal. An example of this type of switch was the Sima (**www.simacorp.com**) SVS-4D. Even though it was a bit pricey, I considered purchasing one, but — when I found it was not locally available — I started thinking this would be an interesting project to tackle. It couldn't be that hard, right?

A/V Switching 101

I can't imagine what it was like researching a project like this before the Internet. I knew virtually nothing about A/V switches, but — in 15 minutes — I had a number of switch schematics and a couple of articles on the subject. I discovered that the actual switching part is pretty straightforward. Virtually all of the designs that I looked at were based on multiplexer chips.

Video switching can be accomplished easily with a Maxim (**www.maxim.com**) MAX454. This integrated circuit contains a four-way video multiplexer with a built-in amplifier. Output is high quality with low phase distortion. Similarly, audio can be cleanly switched with a MAX399 — a dual four-channel analog multiplexer. In both cases, video and audio inputs are selected via a pair of address lines.

Are You There?

How do you know if there is an active video signal

present? This is a key requirement for this project and the one aspect that I failed to find definitive (easy) Internet answers for.

There were, however, some clues, but you first have to understand what makes up the NTSC composite video signals we will be dealing with.

Composite video gets its name from the fact that it combines three different signals — video data, color data, and synchronization information — all in one line. For the NTSC standard, the video (or luminance) information consists of DC voltage levels between 0.48 and 1.2 volts.

Synchronization signals (horizontal and vertical) also use voltage levels for synch pulses that are always below the video data "black" level. The normal synch level is at 0.4 volts and the active synch pulse for NTSC is at 0 volts.

Finally, the color (or chrominance) information is encoded by changing the phase of a 3.579 MHz sine wave analog carrier signal.

First Attempt

One suggestion I found to the video detection problem was to use a "video sync separator" like the LM1881 from National Semiconductor. This chip extracts the timing information from the composite signal including vertical and horizontal synch. The idea is to use a microprocessor to monitor these timing signals looking for valid composite patterns like, for instance, detecting 60 vertical synchs per second.

I breadboarded this solution using a PIC12F625 microprocessor (**www.microchip.com**) and found that it was quite an effective video detector. While testing, though, I discovered that both my digital cable box and media player generated valid composite video synch signals even when they were powered off (in standby mode). Okay, back to the drawing board.

Try Again

Detecting the presence of a composite video synch signal turns out not to be enough for this project. You have to determine whether there is a picture present or not. It occurred to me that, since the video luminance signal is specified to be between 0.48 and 1.2 volts, all you had to do to detect images is look for a voltage higher than 0.48 volts.

So, I modified the breadboard setup and reprogrammed the 12F625 PIC to sample the video using the built-in ADC. With the PIC running at 4 MHz, I was able to check the signal about 10,000 times per second. By keeping track of the largest detected voltage value over a fixed sample period, I was indeed able to distinguish between a video signal with an image and the "blank" screens sometimes presented by devices in

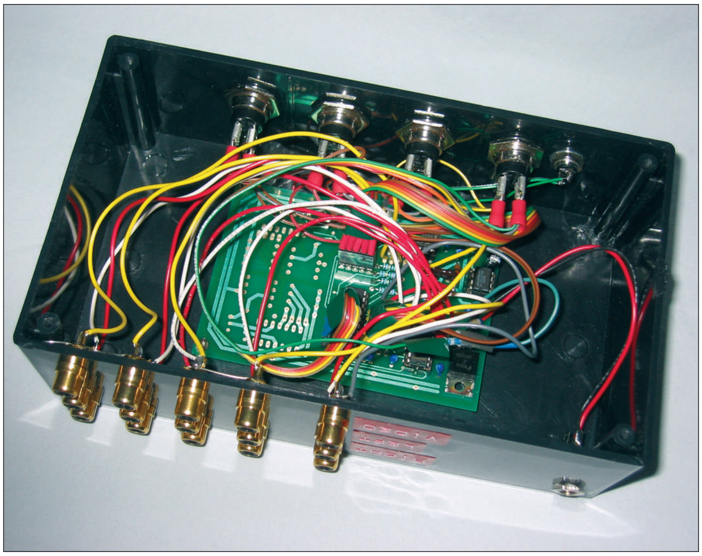


Figure 2. Inside the prototype, the wiring can get a bit complex.

"standby" mode.

In fact, it worked so well that I was able to drop the LM1881 from the design. Since the video sync signals all fall below the 0.4 volt threshold, they have no effect on the video sampling.

Figure 3. The completed unit, seen from the back.

How Would It Work?

With the basic technical particulars understood, I had to decide in detail how I wanted the switch to work. I settled on a scheme where the four inputs would be assigned a priority. The switch will automatically select the "active" input with the highest priority and turn on an LED for that input to indicate that it is selected.

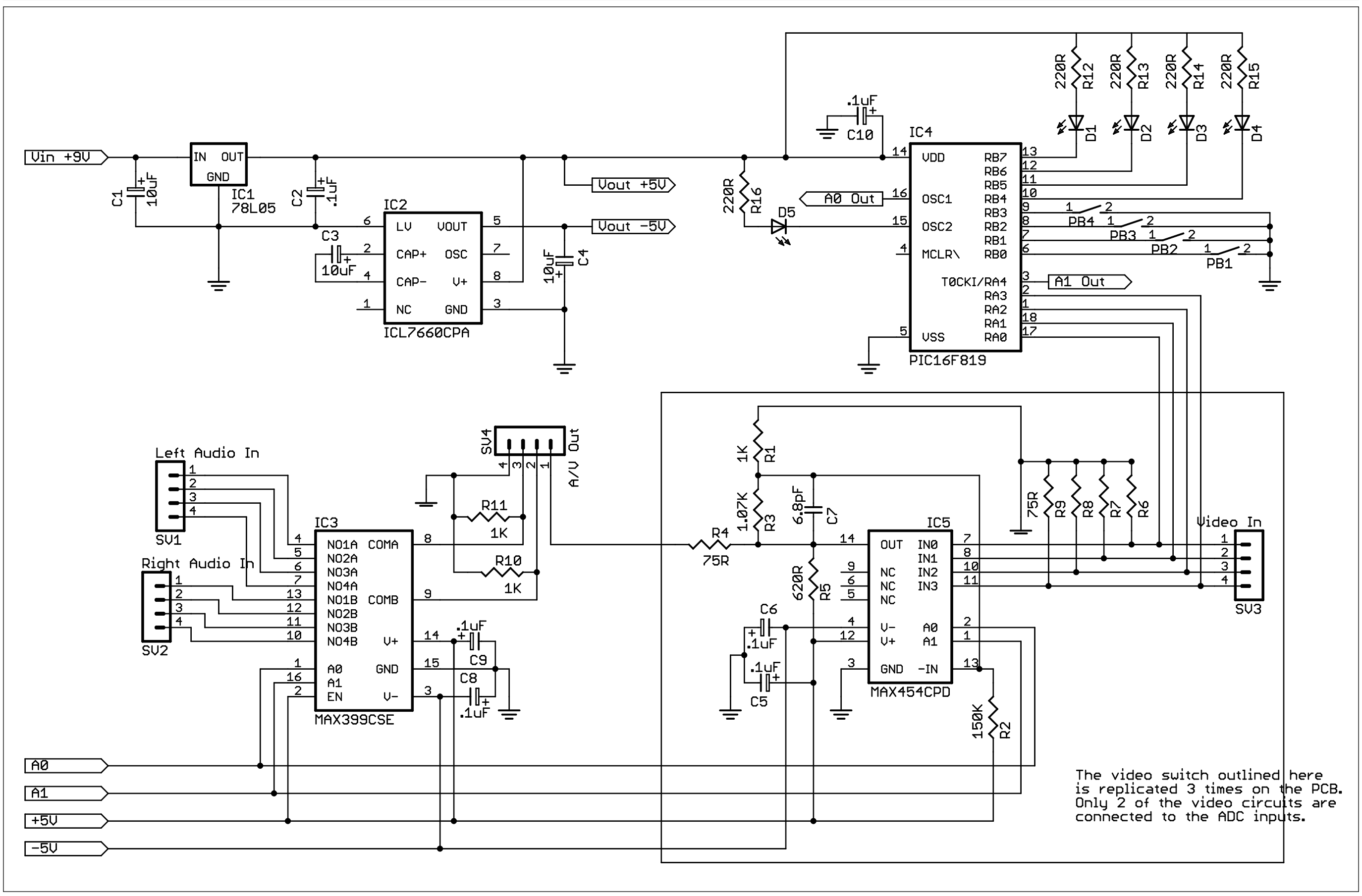
While automatic is nice, there will be occasions when you want to manually "override" the current selection. For this, a button for each input will be provided with an additional LED to indicate that an input has been overridden. Press a button once to manually select an input; the override LED will light up. Press the same button again to cancel override and revert to auto selection.

The Schematic

The final circuit can be seen in the schematic provided. You will notice that provision has been made to switch up to three independent video signals. Although my current needs are strictly for single NTSC composite video signals, since my older TV has only cable and composite inputs, I anticipate that — in the near future — I will upgrade to a system with s-video (with two video signals) or component video (three signals). I believe that this circuit can handle all three formats, but have only tested the composite case.

The video circuit itself is based on the "low phase distortion" reference design in the Maxim MAX454 technical reference document. Inputs are terminated with 75 Ω resistors. The gain of the internal video amplifier is

Figure 4. The schamtic showing the controller PIC and video switch and bipolar voltage source.



set to 2 to compensate for any loss as a result.

An AC adapter and a 78L05 voltage regulator provide the power. Both the MAX454 and the MAX399 require ±5 volts, so an LTC660 voltage converter is used to get the inverted voltage.

At the heart of the project is a PIC 16F819 microprocessor. This device has a built-in ADC that can be used with up to five inputs. By using the internal oscillator, there are just enough available I/O pins to handle the buttons and LEDs.

Which Ground?

I was disappointed when the first breadboard setups of the circuit produced an unacceptable amount of interference in the switched video output. Since most of my work prior to this project was purely "digital," I was unaware of the concept of an "analog ground."

For a mixed mode circuit like this one, the analog components should have a separate ground signal, which is connected to the digital ground via a single point in the design (as close to the power supply as possible). Once I had rearranged my breadboard prototype to take this into account, the video signals cleared right up.

Construction

Due to the relative complexity of this project, I decided to create a custom PCB. I used Cadsoft Computer's (**www.cadsoft.de**) excellent Eagle Layout Editor to design the board. Not only is the price right for this package (free for hobby use with some restrictions), an increasing number of "boardhouses" will accept Eagle "BRD" files directly, including Custom PCB Prototyping Services (**www.custompcb.com**), where I had my boards manufactured. (Both the Eagle .sch and .brd files are available for download from the Nuts & Volts website, **www.nutsvolts.com**)

I built the switch into a black project box 7-3/4" wide x 2-3/4" high x 4-1/4" deep, which was a little bigger than it had to be but easier to work with. The buttons and LEDs are panel mount and more expensive than I would have preferred, but the chrome rims give the project a retro look that I really like.

Programming

The PIC does all the real work. It spends its time in a loop, monitoring each of the video inputs for about a quarter second. The ADC is used to repeatedly sample the input and the largest voltage for the sample period is maintained. At the end of the sample period, the largest sample voltage is compared to minimum and maximum thresholds. If the sample voltage is less than the minimum threshold, the video signal is considered to be "off" and, if larger than the maximum threshold, it is "on."

This current state of each input is maintained. Once all of the inputs have been processed, the PIC selects the input with the "highest" priority and switches both audio and video outputs to that input using the address lines of the multiplexer chips. The LED for that input is also turned on.

At the same time as this is happening, the PIC is looking for button presses. When a press is detected and "debounced," the input for that button is enabled and the "override" LED is turned on. A second press of the same button will disable override mode and switch back to auto select.

Performance

I'm extremely happy with the end result. The switch worked very well the first time that I connected it into my system. Video images are clean with no discernable interference introduced by the switch. Detection of video signals and switching is practically instantaneous.

One area that needed a little "fine tuning" was the setting of the minimum and maximum voltage thresholds. Initially, I had a single value for each input; above that value, the input was considered to be "on" and below was "off." With this arrangement, I observed "glitches" where a live input would occasionally "drop out" for a second or two. Setting lower and upper threshold values and tuning those values to the characteristics of each input eliminated this issue.

Conclusions

This project was a lot of fun and I learned a great deal along the way. With the benefit of this experience, there is only one thing that I would consider doing differently if I were starting again. By using panel mount buttons, LEDs, and RCA connectors, I ended up with a lot of wire interconnects to the PCB. Next time, I would think about replacing most of these with PCB mount parts, simplifying the design.

Completing this automatic A/V switch has certainly satisfied the couch potato in me. Now, if I could only think of a way to automatically insert those pesky tapes and DVDs from my couch. Hmmmmm. **NV**

About the Author

Michael Gardi has been writing software for about 30 years, but is relatively new to the world of hardware. Mike lives in Southern Ontario with his wife and two children.

Web-Enabled X-10 Home Automation Controller

Glue Your X-10 Devices to a Webpage

This project uses an Imagine Tools Ethernet Starter Kit and X-10 modules to make a controller that will run X-10-connected lights and appliances without a PC and will also allow you to control and schedule them from anywhere with a web browser.

Think of the possibilities. You're having a stressful day at work or you have a hot date and you want the jacuzzi warmed up when you get home. You forgot to leave the porch light off for your mother-in-law. The list goes on.

The project implements the scheduling and sending of ON/OFF commands to household AC devices from an RCM3710 C-programmable Rabbit Core module included with the Imagine Tools Ethernet Starter Kit, which also includes code library support for X-10. In addition, X-10 power line interfaces and lamp or appliance modules are required. These are not included in the kit and can be purchased directly from X-10 Corporation on the Internet. A few additional diodes and resistors, a transistor, a phone cable, and an RJ11 jack are also needed.

The concepts here can be applied to other Ethernet-enabled programmable controllers, as well. X-10 support is also available for BASIC Stamps. The X-10 protocol is fairly simple. It took me about a work week to implement with a processor and programming tools I was familiar with using a technote available from X-10.

About X-10

The X-10 protocol has been around since the late 70s. It is used to communicate messages between devices plugged into household 120 volt AC power. X-10 power line interface hardware units include the one-way PL513 device which sends messages into the power grid and the two-way TW523 which can both receive and send messages. For countries using 50 Hz power systems, a TW7223 must be used.

A variety of devices that can listen to and respond to the power line interface units are available directly from X-10.

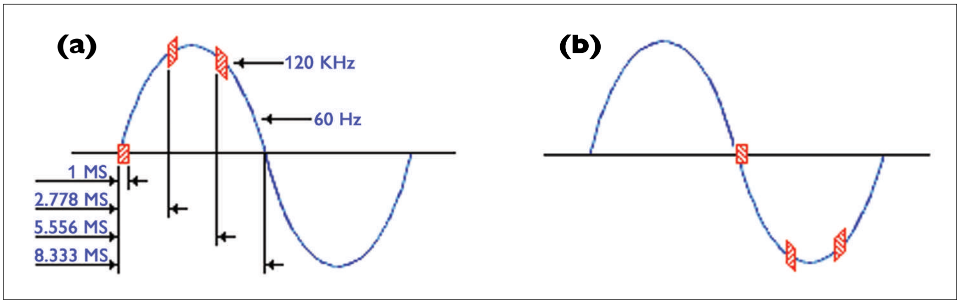
Although some X-10 literature still talks about their patent on the protocol, it is my understanding that the X-10 patent expired in 1997. However, using their UL, FCC approved units for the power socket interfaces rather than making them yourself is still a good way to help you avoid mistakes that could lead to electrocution or homelessness.

For this project, I am limiting discussion to the PL513 interface and LM465 lamp modules. Appliance modules and other modules that accept ON/OFF commands can be substituted for the LM465s with no change in the interface circuitry or software. For simplicity, I will refer only to the PL513 and LM465s here. The PL513 is an OEM device that requires some additional circuitry to interface it to a programmable controller.

The X-10 Protocol

X-10 uses a series of "bit" sequences to communicate messages, but — as you can imagine — a bit transmitted over AC power lines is more complicated than the simple ON/OFF or LOW/HIGH bit of digital circuitry. The transmission of a "one" bit consists of three 1 millisecond length bursts of a 120 KHz signal superimposed on the AC signal in the first half-cycle after the zero crossing, followed by nothing in the second half of the cycle, as shown in Figure 1A.

Figure 1. (a) An X-10 one bit. (b) A zero bit. Courtesy of X-10.



Three bursts are used so that X-10 will work in a three-phase

Skills

Hardware Construction: Rating 2
This is a very simple circuit. If I can put it together, anyone can!

Software: Rating 3
Some of the software is complex for the novice, but it is already written for you.

HOUSE CODES

	H1	H2	H4	H8
A	0	1	1	0
B	1	1	1	0
C	0	0	1	0
D	1	0	1	0
E	0	0	0	1
F	1	0	0	1
G	0	1	0	1
H	1	1	0	1
I	0	1	1	1
J	1	1	1	1
K	0	0	1	1
L	1	0	1	1
M	0	0	0	0
N	1	0	0	0
O	0	1	0	0
P	1	1	0	0

KEY CODES

	D1	D2	D4	D8	D16	
1	0	1	1	0	0	
2	1	1	1	0	0	
3	0	0	1	0	0	
4	1	0	1	0	0	
5	0	0	0	1	0	
6	1	0	0	1	0	
7	0	1	0	1	0	
8	1	1	0	1	0	
9	0	1	1	1	0	
10	1	1	1	1	0	
11	0	0	1	1	0	
12	1	0	1	1	0	
13	0	0	0	0	0	
14	1	0	0	0	0	
15	0	1	0	0	0	
16	1	1	0	0	0	
All Units Off	0	0	0	0	1	
All Lights On	0	0	0	1	1	
On	0	0	1	0	1	
Off	0	0	1	1	1	
Dim	0	1	0	0	1	
Bright	0	1	0	1	1	
All Lights Off	0	1	1	0	1	
Extended Code	0	1	1	1	1	
Hail Request	1	0	0	0	1	1
Hail Acknowledge	1	0	0	1	1	
Pre-Set Dim	1	0	1	X	1	2
Extended Data (analog)	1	1	0	0	1	3
Status=on	1	1	0	1	1	
Status=off	1	1	1	0	1	
Status Request	1	1	1	1	1	

Table 1. House and key codes. Courtesy of X-10.

power distribution system. A zero bit consists of nothing in the first half-cycle followed by three bursts in the second half-cycle, as shown in Figure 1B.

The exception to this pattern of following a 1 or 0 bit with its compliment in the second half of the cycle is the start code, which consists of three 1 bits in three half-cycles followed by a zero bit in the fourth. After the start code is sent, a house code and a key code are sent.

The house code is a four-bit number and the key code is a five-bit number. The house and key codes correspond to the house and unit number addresses of receiving devices which are set by turning dials on the LM465 units.

After the start/house/key code sequence, a second start/house/key code sequence is sent. This time the key code is a function code that specifies the X-10 command (ON,OFF, etc.). Three power cycles of no bits must follow each of these groups of six numbers before the next command is sent. The exception to this is BRIGHT/DIM commands, which don't require a three cycle gap, and which we don't use in this project, but the adventurous reader is free to add.

Table 1 is partial list of house and key codes. Note that an unusual numbering system is used; for example, 13 is represented by five zero-bits — your guess as to why is as good as mine. Note that the bit codes are transmitted in the order H1 ... H8 and D1 ... D16.

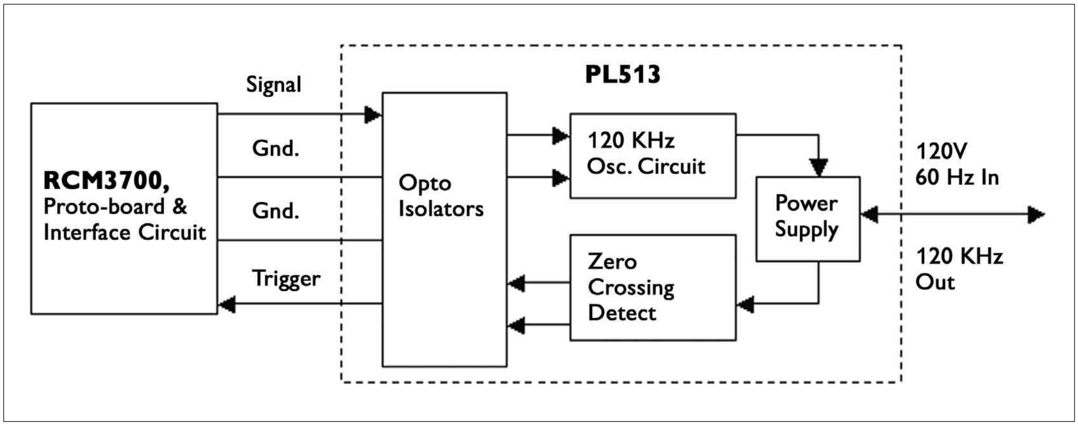
PL513/RCM3710 Interface Circuit

The RCM3700 isn't responsible for generating the 120 kHz, 1 ms bursts needed for X-10 communication. Although it could handle the task, it would complicate the programming a bit and take away a lot of CPU time from networking tasks. It only needs to assert a 5 V signal for 1 ms when a burst is required. The PL513 generates the 120 kHz output signal while its digital input is high (5-24 V).

This and providing the zero-crossing output so the RCM3710 can synchronize its output are the only things that the PL513 does. The input and output of the PL513 are optically isolated. Figure 2 shows a block diagram of the PL513.

The zero-crossing output of the PL513 is sinusoidal and needs to be made into a square wave to achieve proper timing for the microprocessor external interrupt that detects it. The 3.3 V digital, open drain output of the RCM3710 needs to be pulled up to 5 V. The circuit in Figure 3 is a reference design provided by X-10 Corporation.

Figure 2. PL513 block diagram.



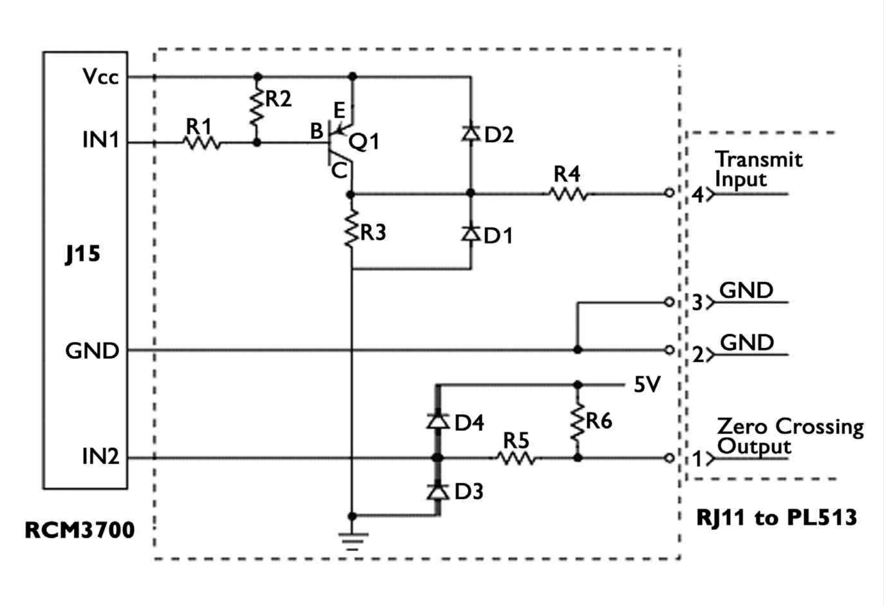


Figure 3. The RCM3700-PL513 interface circuit.

Notes on Circuit Design:

• IN1 is configured as input or output by software; it is output here. The two grounds on the PL513 are not common on that unit; both must be connected to the RCM700 ground. IN2 is configured as an external interrupt in software.

• GNDs ↔ RJ11 RED & GREEN; Transmit Input ↔ RJ11 YELLOW; Zero Crossing ↔ RJ11 BLACK

The Imagine Tools Kit has a solderless breadboard you can build the circuit on to test it and a small prototyping area on the development board you can solder the parts onto afterward.

Readers interested in more details about the PL513 hardware can find more information in this application note, which includes a schematic of the unit: **http://software.x10.com/pub/manuals/technicalnote.pdf**

Software

For space considerations, I will mainly discuss the low level software interface to the PL513 in detail here.

Sending X-10 Commands

X-10 commands are sent by filling an array of one byte values with 1s and 0s representing the stream of bits needed for a complete command. Space could be saved by compressing this down to a bit stream, but the logic for walking through the bit stream would be more complicated than if we simply use byte values to represent bits. Most controllers capable of running a web browser have plenty of RAM available anyway.

Once the bit array is ready, a global bit counter and pointer into the bit stream are initialized and the external interrupt connected to the PL513 zero-crossing detect line is enabled. When the zero-crossing is asserted, the processor interrupts whatever it is doing and execution jumps to the external Interrupt Service Routine (ISR). The external ISR initializes the timer ISR. The timer ISR contains a small state machine that runs for one power cycle and handles sending the millisecond length signals to the PL513.

When the power cycle is complete, the timer ISR disables itself. On each zero-crossing, the external ISR checks to see if the command transmission is complete and reenables the timer ISR to cycle through the states again, if needed.

The Rabbit 3000 Processor has multiple 10-bit countdown timers on-chip. The counter match registers for a timer can be initialized to any value between 0 and 1,023. We set up the timer to count down every other clock cycle.

Listing 1. C code for function to send X-10 command bit string.

```
/* Global variables */
int  x10SendPending, x10_matchCount, x10_bitCount;
int *x10_bitPtr, *x10_state;
char x10_code[MAX_COMMAND_SIZE];

SendBitString(char* bitstring, char nbits) {
/* Can't start a command until last one sent */
/* The external ISR resets the flag to zero when done */
   if(x10SendPending)  { return -1; }
   x10SendPending = 1;

/* Copy string to global transfer buffer */
/* unless bitstring is the transfer buffer */
   if(bitstring!=x10_code)
      memcpy(x10_code, bitstring, nbits);

/* Init. Timer state machine */
   x10_state = (unsigned)State1;

/* set for 1rst 1 ms burst */
   x10_matchCount  = MS_MATCHNUM;
   x10_bitPtr = x10_code;        /* Init bit string ptr  */
   x10_bitCount = nbits;         /* Init bit counter    */
   EnableExternalISR();
   return 0;
}
```

When a timer interrupt is enabled, the processor interrupts when the count reaches the match value and code execution is transferred to the timer ISR. Running at 22 MHz, it takes 11 rollovers to time 1 millisecond and 19 rollovers to time the interval between the 1 millisecond signal. A global variable counts rollovers between state transitions.

Most of the time, the timer ISR just increments the rollover count and checks whether it has reached 11 or 19, depending on whether 1 millisecond or a gap is being timed and exits quickly when it hasn't. Every 11th or 19th interrupt, it runs a few extra instructions to service the state machine and change the state variables, bit counter, and pointer if the state falls on the edge of a half power cycle.

Listing 1 shows the function that starts the sending of an X-10 bit string. A return value of -1 means that a command is already being sent. It must be called until it returns zero.

In the absence of a preemptive multi-tasking operating system, this means running other code from a main loop if SendBitString returns a value of –1, then calling the function to try again.

Once a command transmission is initiated, it is completed by the external and timer ISRs in the background. (Processors without external interrupts and timer

Listing 2. Pseudo-code for ISRs.

```
//**** External Interrupt ISR ****
BEGIN:
   // (Assume interrupts disabled on entry)
   Save context
   x10currentBit ← @x10_bitPtr
   IF( x10currentBit = 1)
        Assert output line
   IF(x10_bitCount = 0)
        GOTO Done
   Timer match registers ← 0
   x10_matchCount ← 0
   Enable timer interrupt
   goto Exit
Done:
   Disable external interrupt
   x10SendPending ← 0
Exit:
   Restore context
   Enable interrupts
   RETURN
END

//***** Timer ISR ****
BEGIN:
   //  (Assume interrupts disabled on entry)
   Save context
   clear interrupt source
   Timer match registers ? 0
   x10_matchCount ← x10_matchCount - 1
   IF( x10_matchCount ≠ 0 )
        GOTO Exit
   IF( x10currentBit = 1 )
        Assert output line
   else
        Deassert output line
   GOTO @x10_state
State1:  // Done sending first bit
   x10_matchCount ← 19
   x10_state ← State2
   GOTO Exit
State2:  // start sending 2nd bit
   x10_matchCount ← 11
   x10_state = State3
   GOTO Exit
State3:  // done sending 2nd bit
   x10_matchCount ← 19
   x10_state ← State4
   GOTO Exit

State4:  // start sending 3rd bit
   x10_matchCount ← 11
   x10_state ← State5
   GOTO Exit
State5:  // done sending 3rd bit
   x10_matchCount ← 19
   x10_bitPtr ← x10_bitPtr + 1
   x10_bitCount ← x10_bitCount - 1
   x10currentBit ← @x10_bitPtr
   x10_state ← State6
   GOTO Exit
State6:   // start sending 4th bit
   x10_matchCount ← 11
   x10_state ← State7
   GOTO Exit
State7:  // done sending 4th bit
   x10_matchCount ← 19
   x10_state ← State8
   GOTO Exit
State8:   // start sending 5th bit
   x10_matchCount ← 11
   x10_state ← State9
   GOTO Exit
State9:  // done sending 5th bit
   x10_matchCount ← 19
   x10_state ← State10
   GOTO Exit
State10:  // start sending 6th bit
   x10_matchCount ← 11
   x10_state ← State11
   GOTO Exit
State11:  // done sending 6th bit
   Disable Timer interrupt
   x10_bitPtr ← x10_bitPtr + 1
   x10_bitCount ← x10_bitCount - 1
   x10currentBit ← @x10_bitPtr
   x10_matchCount ← 11
   currentStateLabel ← State1
Exit:
   Restore context
   Enable interrupts
   RETURN
END
```

Listing 3. Main program and HTML code.

```
/********* Dynamic C Source file X-10Toggle.c ***********
#define TCPCONFIG 1
#define USE_RABBITWEB 1
#use “hobbyist.lib”
#use “dcrtcp.lib”
#use “http.lib”
#use “X-10.lib”
#ximport “/X-10page.zhtml” X-10page   SSPEC_MIMETABLE_START
      SSPEC_MIME_FUNC(“.zhtml”, “text/html”, zhtml_handler)
SSPEC_MIMETABLE_END
SSPEC_RESOURCETABLE_START
      SSPEC_RESOURCE_XMEMFILE(“/index.zhtml”, X-10page)
SSPEC_RESOURCETABLE_END
char onOff[4];
#web onOff         // Make onOff  web accessible

main() {
      HBx10_Init();
      sock_init(); http_init();
      http_set_path(“/”, “index.zhtml”);
      tcp_reserveport(80);
      while(1){
         onOff[0] = 0;
         http_handler();    // Run HTTP server tick
         if(!strcmp(“On”,onOff))
              while(HBx10_SendCommand(‘A’,1,X-10_ON));
         else if(!strcmp(“Off”,onOff))
              while(HBx10_SendCommand(‘A’,1,X-10_OFF));
      }
}

/********* HTML Source file X-10page.zhtml **********
<HTML><HEAD><TITLE>Toggle X-10</TITLE></HEAD>
<BODY>
Toggle X-10 device<br>
<FORM  method=”post” action=”/index.zhtml”>
<INPUT TYPE=”submit” name=”onOff” value = “Off” ><P>
<INPUT TYPE=”submit” name=”onOff” value = “On” >
</FORM>
</BODY>
</HTML>
```

interrupts must use other methods such as polling an input line.) The SendBitString function is not used directly by the programmer, it is called by a higher level API function which returns the return value of SendBitString. Listing 2 shows the pseudo-code for the timer and external ISRs. The actual Rabbit assembly code can be seen in X-10.LIB.

Higher Level Code

The application programming interface for X-10 is very simple for the Imagine Tools Kit. `HBx10_Init()` is the function that initializes the interrupt vectors and I/O pins. `HBx10_SendCommand(HouseCode, KeyCode, FunctionCode)` creates the bit strings and sends them down to the lower level code described earlier.

The C and HTML source code for the full project is too long to show here, but Listing 3 shows a bare bones example of an X-10 web/controller interface. The standard HTML method of defining a button to set the value of a program variable is shown; in this caseit is the character array “onOff.”

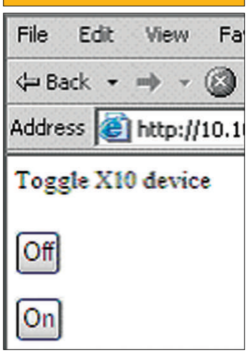
I used Z-World’s RabbitWeb web extensions on the C side to define the array variable as web accessible with a simple compiler directive. This program hard codes a house code of “A” and a key code of 2 (the keycode parameter range is from 0-15, while the UNIT dial on the LM465 goes from 1-16). An LM465 should be plugged into a wall socket, have a lamp plugged into it, have “UNIT” set to 2, and “HOUSE” to A.

Putting It All Together

Now that you know how X-10 works and how to create browser interfaces to a programmable controller, you should have no problem creating a complete, run time configurable home automation system like the one shown in Figure 5, but you can save a fair amount of time by using the complete, ready to compile and load RCM3710 source code (HOMEAUTO.C is the program file) and HTML code for the project available on the *Nuts & Volts* (**www.nutsvolts.com**) and Imagine Tools websites (**www.imaginetools.com**). This program allows the user to remotely toggle devices, add and delete devices, and create schedules for turning devices on and off. It includes password protection.

For readers who want to expand the capability of the system, the X-10 library has support for any transmitted X-10 command. The RCM3710 prototyping board includes several extra digital I/O and an ADC. The truly adventurous

Figure 4. Simple web page interface.



Useful Websites

X-10
www.x10.com

Imagine Tools / Z-World
www.imaginetools.com

LakeView Research
(great book for beginning network programmers)
www.lvr.com/eec.htm

Mouser
www.mouser.com

could implement X-10 reception for a TW523 unit.

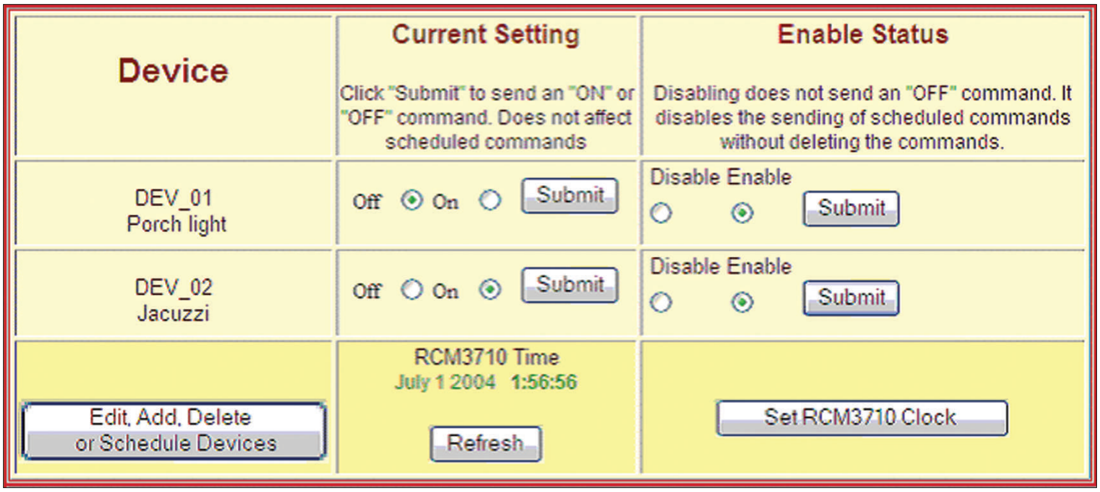


Figure 5. Main web page interface of the home automation project.

Connecting to the Internet

You will need some kind of a switch or router to connect your controller to the Internet. However, you could plug an Ethernet crossover cable (one is included with the Imagine Tools kit) directly into your PC's Ethernet port if you just want to configure your X-10 controller from your browser, but not access it from the Internet. I used my old D-Link firewall on my home PC, which allowed me to configure an IP address to use for the X-10 controller.

Nowadays, it is a good idea to have firewall protection for your PC and they aren't expensive. Unfortunately, you won't be able to put your X-10 controller on the Internet if you only have dial-up modem access without jumping through some hardware and software hoops which are beyond the scope of this article.

In order to get an extra IP address to use for the X-10 project, I asked my Internet Service Provider (ISP) and they gave me one for $5.00 extra per month. I'm sure this varies from ISP to ISP.

The macro TCPCONFIG should be #defined to 1 for normal configuration. It is possible to set it to 3 to use Dynamic Host Configuration Protocol (DHCP), but this will only be useful if you have no other devices using DCHP and you know what IP address DHCP will assign, so it's not recommended.

When using TCPCONFIG=1, the macros _PRIMARY_STATIC_IP, _PRIMARY_NETMASK, and MY_GATEWAY macros defined in the file /libraries/tcp_ip/TCP_CONFIG.LIB need to be set to the correct values for your system.

This and defining your own username and password are the only code changes required to run the HOMEAUTO.C program. The rest is run time configuration using the browser interface.

To access your X-10 controller with your browser once it is up and running, enter http://x10address in the address box of the browser, where x10address is the dotted decimal xxx.xxx.xxx.xxx form of the IP address.

As a final note, never put anything critical or potentially dangerous under X-10 control. There is no way to confirm if a command was successful, since the power line communication is one-way.

Noise on the power lines could corrupt a command and cause it to fail. If your power lines are not well isolated from your neighbor's, it is possible for their X-10 controls to send commands to your devices and vice versa if you both use the same house codes on a device. Have fun! **NV**

About the Author

Brian Murtha has been designing and writing software for 15 years. He works for Z-World/Rabbit Semiconductor Marketing as Director of Software Applications.

Parts List

Part	Description	Supplier/Part #
Controller	Imagine Tools Ethernet Starter Kit	Mouser / 609 101-0936
PL513	X-10 power line interface	X-10 (also available from Parallax)
LM465	X-10 Lamp module (one per controlled device)	X-10 (also available from Parallax)
Q1	TO-92 PNP transistor	Mouser / 512-2N3906_D11Z
D1, D2, D3, D4	IN904 diodes	Mouser / 78-1N914
R1, R2, R3	10K ohm, resistors	Mouser / 299-10K
R4, R5	100K ohm, resistors	Mouser / 299-100K
R6	5.1K ohm resistor	Mouser / 299-5.1K
RJ11 jack	4-wire phone cable jack	Mouser / 154-7652A4
RJ11 cable	7' cable with connectors	Mouser / 154-3001

by Don Powrie

Multi-Protocol USB

Using FFTs to Whistle Your Way to Home Automation

The vast majority of USB devices available on the market today have at least one thing in common: They all use microcontrollers to implement the task at hand. Whether it's in the form of a USB serial engine sharing the same piece of silicon with a microcontroller or a simple connection between the two on a printed circuit board, the use of a microcontroller for just about any USB-based task is virtually inescapable ... that is, until now.

In the arena of "easily-implemented USB," the folks at FTDI (**www.ftdichip.com**) have done it yet again by releasing their new, dual-channel FT2232C IC. This new chip offers two interfaces for connection to user electronics, as compared to its predecessors (the FT232BM and FT245BM) that only have one. Instead of being fixed in hardware as only serial (USB-UART) or parallel (USB-FIFO), both channels of this new chip are configurable for serial, parallel, or one of several other new interface modes of operation.

This article will focus on one of the new interface modes — known as the Multi-Protocol Synchronous Serial Engine or MPSSE. The MPSSE interface is only available on one of the two channels and consists of a clock line, a data IN line, a data OUT line, and some general purpose digital I/O lines. The MPSSE can be controlled via any programming language with the ability to open, load, and access a Dynamically Linked Library (DLL). I wrote my program in Visual C++ to demonstrate the MPSSE, but

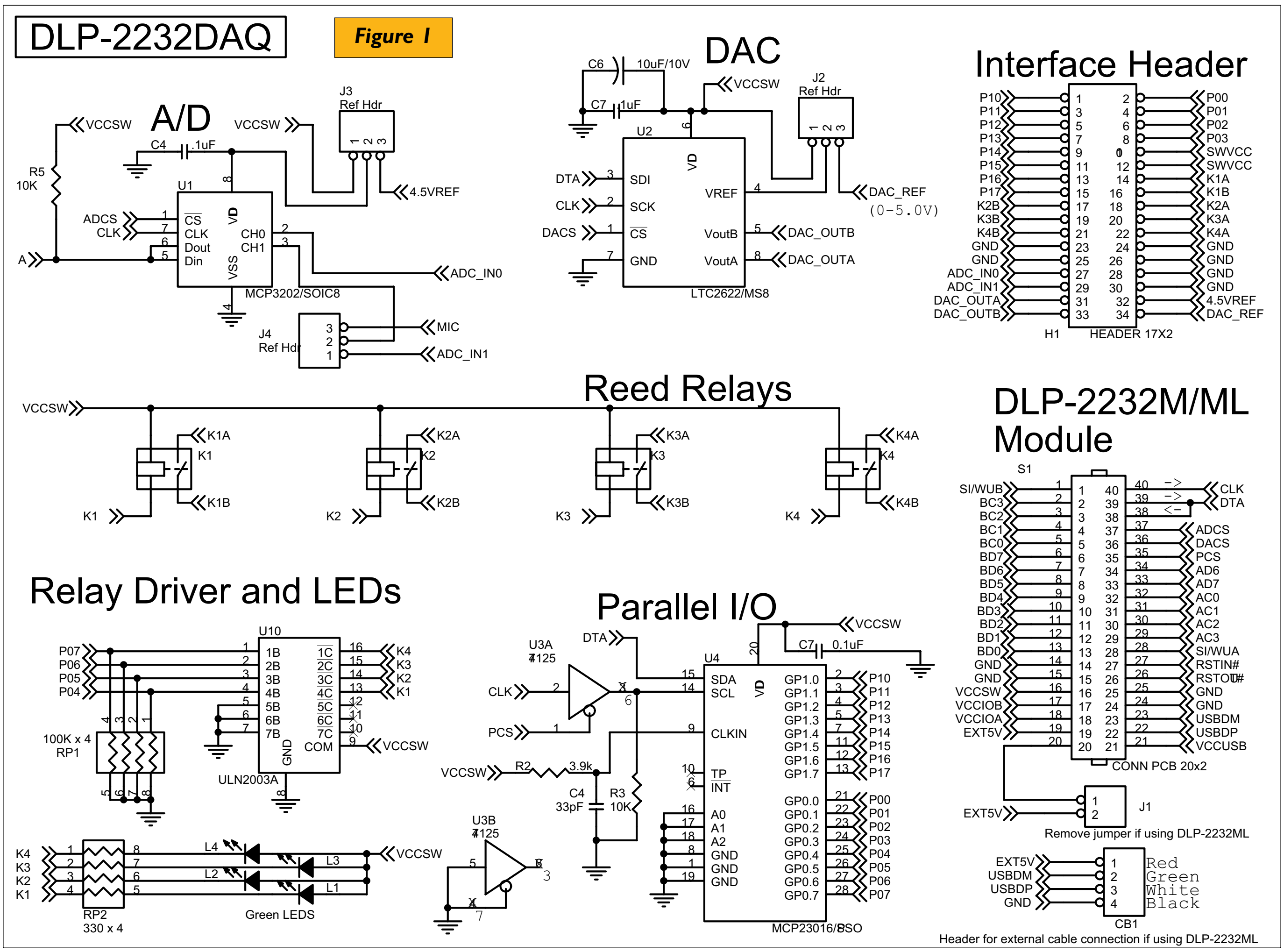


Figure 1

Visual Basic and other programming languages can be used, as well. (We'll talk more about software later.)

I will further demonstrate how to use the MPSSE to communicate with a 12-bit A/D converter, a 12-bit DAC, 12 digital I/O lines, and control four relays — all without the use of a microcontroller and all without any in-depth knowledge of USB!

Hardware Design

A printable version of the schematic (Figure 1) is available for download as a PDF document from the *Nuts & Volts* website (**www.nutsvolts.com**).

A picture of the prototype printed circuit board is shown in Figure 2. The picture shows the prototype using the DLP-2232M, but it could be used with either the DLP-2232M or DLP-2232ML dual channel USB interface modules.

The data acquisition devices used in this design all have serial interfaces perfect for use with the MPSSE. The data IN and data OUT lines of the MPSSE are connected at the DLP-2232M(L) interface to form a single, bi-directional data line. This data line and the clock line are shared between all of the acquisition devices in the design and each device is enabled for communication via one of the general purpose digital I/O lines on the FT2232C.

Figure 3 shows a simplified block diagram of the data acquisition system.

The A/D is a dual channel, 12-bit, successive-approximation converter that was chosen for its low cost and small size. The intention of this hardware design was more to show off the capabilities of the MPSSE and less to provide a large scale or highly accurate data acquisition system. That said, 12 bits (1.2 millivolt resolution) is likely to be more than enough for most voltage measurements on the 0-5 volt range.

Since the voltage reference for this converter is tied to the VDD line internally, VDD is the reference and can be any value from 4.5-5.5 volts. Since this A/D is communicating digitally with a 5 volt system, taking VDD below 4.5 volts could cause damage and would definitely affect accuracy. In this design, the VDD line for the converter is brought out to the interface header via J2 and either the 5 volt supply from the USB port can be used or an external voltage can be provided through H1. For most applications, the 5 volt power from the USB port should work just fine.

The DAC employed in this design is also a 12-bit, dual channel device that has its reference voltage pin brought out to interface Header H1. If Jumper J3 is set to positions 1 and 2, the output voltage range will be from 0 to approximately 5 volts — or whatever the voltage is currently on the USB port. If Jumper J3 is set to positions 2 and 3, then an external reference can be used in the range of 0-5 volts. For example, if an external voltage reference of 2 volts is used, then the output voltage range of the DAC will be 0-2 volts with a resolution of 490 microvolts (2.0/4,096).

The chip used to implement the 12-bit digital I/O bus (also referred to as an I/O expander) is a Microchip MCP23016 and it can have each of its I/O lines configured as either input or output. Since the I/O expander does not have a chip select line, an external buffer (U3) was used to prevent the clock line from initiating a reply on the data line while the MPSSE is communicating with another device.

The four relays used in this design are SPST reed relays and they require very little current (10 mA) to energize their internal 5 volt coil — perfect for USB port-powered applications. They do not need internal protection diodes since the ULN2003A already has the protection diodes built in. When the MCP23016 first powers up, its I/O pins are set to input, so 100K pull-down resistors were added to ensure the relays would all be off.

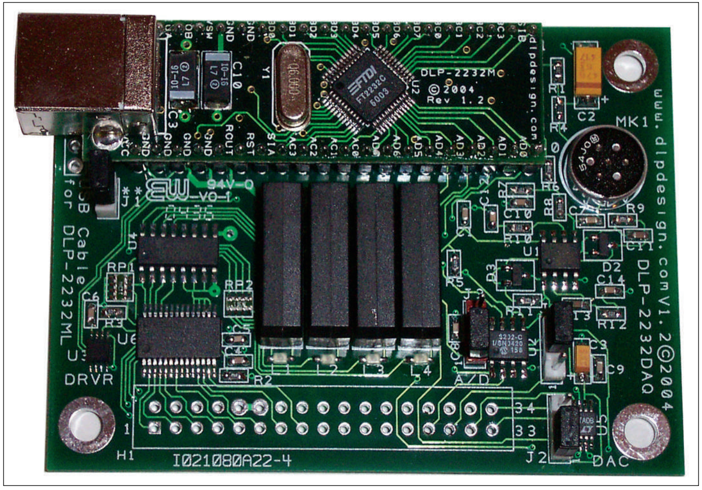
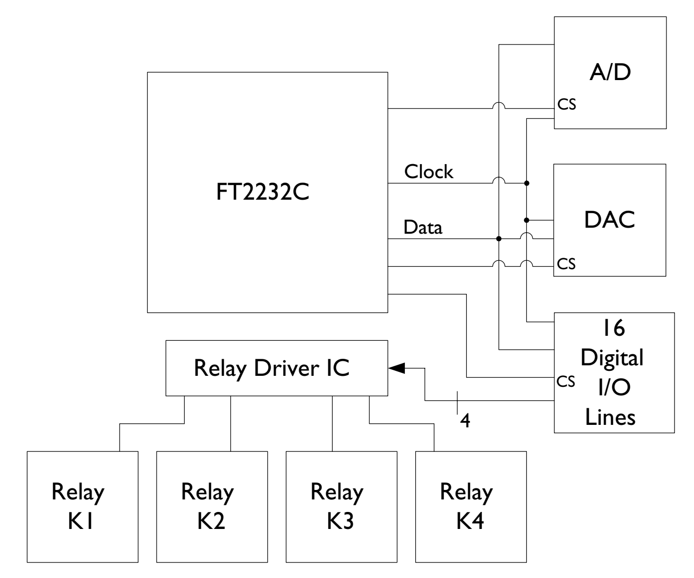


Figure 2. Prototype with DLP-2232M.

Figure 3. Simplified block diagram.



FT2232C

The best source of information on the FT2232C is, of course, the data sheet. To briefly summarize some of its high points, the two channels of the chip can be individually configured to use either the Virtual COM Port drivers (These make the port look like an RS232 serial port to the host application.) or the DLL drivers. Each channel can be configured for any of the various modes of operation (although MPSSE is only available on Channel A) and these selections are made via writing to an EEPROM device that is connected to the FT2232C.

Other new modes of operation for this device are Synchronous Bit-Bang Mode, a CPU-style FIFO Interface Mode, MCU Host Bus Emulation Mode, and Fast Opto-Isolated Serial Interface Mode. Additionally, a new high-drive level option means that the device UART/FIFO I/O pins will drive out at around three times the previous power level, meaning that the bus can be shared by several devices. Classic BM-style Asynchronous Bit-Bang Mode is also supported, but it has been enhanced to give the user access to the device's internal RD# and WR# strobes.

Both channels of the FT2232C are "full-speed" USB devices, but — since there is only a single connection to the host — the combined data throughput for both Channels A and B will not exceed a maximum of about 8 megabits per second.

The true power of the chip is perfectly illustrated when both channels are used in a design in which a programmable device is reconfigured in real time "on the fly." One example of this would be an FPGA configured via the MPSSE on Channel A. Once configuration is complete, Channel B is then used to communicate with the FPGA at full speed. Another example would be to use the MPSSE to write hex program data to the Flash program memory area of a microcontroller with Channel B communicating with the micro at run-time.

Programming

As mentioned earlier, to enable and access the MPSSE, you must use FTDI's DLL drivers. Visual C++ demo source code that demonstrates the use of the DLL is available for download from the *Nuts & Volts* website, listed earlier. Using the MPSSE requires the use of a programming language that can open and access a DLL at run-time. The first step in using the DLL is to open the DLL and load the functions. The application will only be able to do this if the DLL drivers have been loaded onto the computer and the drivers can only be loaded by connecting an FT2232C USB chip to the computer. Once the drivers are properly loaded, the attached USB chip will appear in Device Manager under "Universal Serial Bus Controllers."

Hint: It's a good idea to keep Device Manager open any time you are developing a new product around these USB chips, just to make certain that Windows is properly accessing the hardware.

Once the DLL drivers are opened and loaded, simple function calls are used to open a communications port and enable the MPSSE. To use the MPSSE, begin by setting the speed at which the MPSSE will clock out data. Then select a clock/data scheme that works with the connected hardware. In the case of our A/D converter, we want commands to be clocked in and conversion results to be clocked out on the rising edge of the clock. MPSSE commands 0x13 and 0x20 will accomplish these tasks. (FTDI App. Note AN2232C-01 outlines all of the features of the MPSSE and is available for download from **www.nutsvolts.com** or **www.ftdichip.com**) Since the MPSSE uses a rather low-level coding method, adding comments to your code is key to understanding what you've done the next day when you look at the code again.

Before the MPSSE can communicate with the A/D, its chip select line (ADCS) must be enabled by taking it low. This is accomplished with the command 0x80. Following is a short code example (with comments) for enabling communications and performing a single read of the A/D converter:

```
//take ADCS low
pos=0;
tx[pos++] = 0x80;
//Setup MPSSE Low byte I/O lines
//macro for clearing a bit
CLEAR(LowByteHiLowState, ADCS);
//start with clock low
CLEAR(LowByteHiLowState, CLKSTATE);
tx[pos++] = LowByteHiLowState;
tx[pos++] = OUTPUTMODE;

//send control nibble to ADC
tx[pos++] = 0x13; //Clock out bits, MSB first
tx[pos++] = 0x03; //3 = 4bits
tx[pos++] = AD1; //1111 Start, SnglCh, Ch1, MSBF

//set data direction of AD1 to input
tx[pos++] = 0x80; //Setup MPSSE Low byte I/O lines
tx[pos++] = LowByteHiLowState;
tx[pos++] = INPUTMODE;

//read 2 bytes from A/D conversion
tx[pos++] = 0x20; //Clock out data, MSB first
tx[pos++] = 0x01; //LengthL 0=1byte, 1=2bytes
tx[pos++] = 0x00; //LengthH
//this results in 2 bytes appearing in the RX buffer

//take ADCS back high
tx[pos++] = 0x80;
SET(LowByteHiLowState, ADCS); //take ADC enable high
tx[pos++] = LowByteHiLowState;
tx[pos++] = OUTPUTMODE;

//send the command string
Write(tx, pos, &ret_bytes);
```

The idea is to build a long stream of commands that can be processed at high speed by the MPSSE and send them all at once. The MPSSE will process the entire string of commands at a preset rate and return the data requested by that string of commands (if any) to the data buffer on the host that was created when the port was opened.

DO-RE-MI Whistle Control

By now, you have likely seen the microphone and preamp circuit (Figure 4) and are wondering, "What am I supposed to do with that?" Well, now that we have an A/D converter and an MPSSE that allows us to sample voltages at a known rate, I thought I'd make a listening device that could not only hear someone whistling 30 feet away, but could also calculate the frequency of the note that was being whistled using an FFT and perform a specific operation based upon that note. For example, every time you whistle the note for DO (Remember that movie, *The Sound of Music*? Now I'm showing my age ...) and hold it for one second, toggle the state of Relay K1 to turn on or turn off a fan or, when you whistle the note for MI, take digital I/O line P01 high and then turn it off when you whistle the note for FA.

Since middle C on a piano falls somewhere in the 260 Hz range, you may want to jump up a couple octaves and use the note for C found at about 1,040 Hz. I doubt that anyone can whistle middle C. Furthermore, if you whistle DO, RE, MI starting at 1,040 Hz, you may find it somewhat challenging to hit that last TI and DO. (I cheated a bit and started my DO, RE, ME at 840 Hz so that I could comfortably whistle the entire scale. I'm sure Julie Andrews would be appalled.) Also, you don't have to whistle the exact notes for DO, RE, and MI. Any note you can whistle from about 600 Hz up to 2 kHz can be detected by this system due to the sample rate. Frequencies below 600 Hz are ignored in

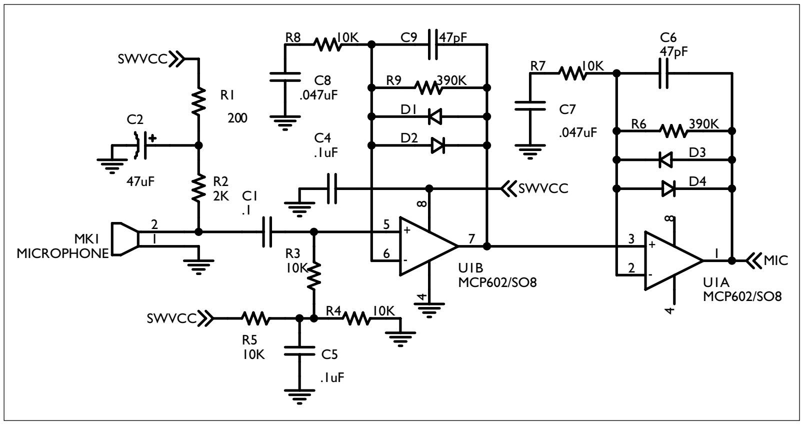


Figure 4. Microphone preamp.

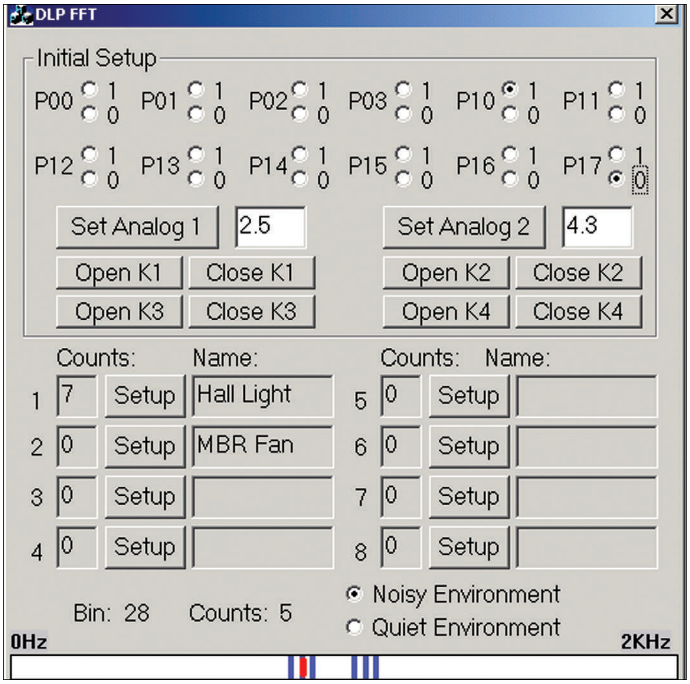


Figure 5. Whistle detection software.

the software, since it's almost impossible to whistle notes this low and these notes tend to appear more prominently in the audio spectrum when the room is otherwise quiet.

If you want to see just what range of frequencies your whistler can handle, download the FFT-based screensaver from the *Nuts & Volts* website; it listens to a microphone via the sound card in your PC and presents the frequency data in real time. (Keep in mind that you shouldn't use this program as an actual screen saver because the frame around the image doesn't change or move and will eventually burn the image onto your CRT.)

An FFT (Fast Fourier Transform) is a mathematical process that converts time domain information to the frequency domain and provides the unique ability to "listen" to each separate portion of the sampled audio spectrum with perfect clarity. If we acquire 128 voltage samples at a rate of 4,000 samples per second and an FFT is calculated, the result of the FFT is frequency domain data evenly divided up into 64 frequency "bins." Each bin holds a single numeric value that represents the overall amplitude of that narrow range (bin) of frequencies.

Okay, it's time for some FFT rules:

1. The FFT is faster than its predecessor — the DFT (Discrete Fourier Transform) — in part because you must provide 2^n (32, 64, 128, etc.) number of input samples.

2. Thanks to work performed back in the 1920s by Henry

Parts List

Item	Reference	Qty	Part	Mfr	Mfr Part #
1	C1,C5,C8,C9	4	0.1µF / 0603	Panasonic — ECG	ECJ-1VB1E104K
2	C3	1	10µF/10V Tantalum	Kemet	T491A106K010AS
3	C4	1	33pF / 0603	Panasonic — ECG	ECJ-1VC1H330J
4	C2	1	47µF, tant	Kemet	T491C476K006AS
5	C11,C13	2	47pF, 0603	Panasonic — ECG	ECJ-1VC1H470J
6	C12,C14	2	.047µF, 0603	Panasonic — ECG	ECJ-1VB1H473K
7	R2	1	3.9K / 0603	Panasonic — ECG	ERJ-3GEYJ392V
8	RP2	1	330 resistor pack	CTS	742C083331JTR
9	RP1	1	100K resistor pack	CTS	742C083104JTR
10	R3,R5-R8,R10,R12	7	10K / 0603	Panasonic — ECG	ERJ-3GEYJ103V
11	R1	1	200, 0603	Yageo	9C06031A2000JLHFT
12	R4	1	2K, 0603	Yageo	9C06031A2001JLHFT
13	R9,R11	2	390K, 0603	Panasonic — ECG	ERJ-3GEYJ394V
14	U3	1	74125 buffer	TI	SN7+4LVC2G241DCTR
15	U5	1	DAC LTC2622	Linear Tech	LTC2622CMS8 / MS8
16	U6	1	MCP23016 / SSOP28	Microchip	MCP23016-I/SS
17	U4	1	Relay driver	Toshiba	ULN2003AFW
18	L1-L4	4	GR LED	Panasonic — SSG	LNJ306G5TR02
19	U2	1	A/D MCP3202	Microchip	MCP3202/SOIC8
20	K0-K3	4	Reed Relay	Coto	9007-05-00
21	J2,J3	2	Jumper, 3-pin	Molex/Waldom	22-03-2021
22	J1	1	Jumper, 2-pin	Molex/Waldom	22-03-2031
23	D2,D3	2	Dual Diode	Fairchild	BAV99
24	MK1	1	MICROPHONE	Knowles Acoustics	MD9745APZ-F
25	U1	1	MCP602/SO8	Microchip	MCP602-I/SN
26	N/A	3	Shorting Jumper	Sullins	SSC02SYAN

Nyquist, we know that the A/D must sample at a rate (known as the Nyquist frequency) that is twice that of the highest frequency we are expecting to find in the frequency domain in order to properly acquire the signal.

3. If the analog signal being sampled has frequency components that are higher than half the sampling rate, then an anti-aliasing filter must be used to filter out these frequencies or the resulting FFT output data will be flawed. A filter of this type is typically a low-pass filter fashioned out of op-amps, resistors, and capacitors.

4. The resulting number of output bins equates to half of the number of input samples.

5. The number of data points taken — not the accuracy of the voltage measurement — dictates the resolution of the frequency domain data.

6. The accuracy of the frequency domain frequency data (i.e., not the amplitude data) is based on the accuracy of the A/D's sampling rate.

For example, let's say our A/D is sampling at a rate of 4,000 samples per second and takes 128 voltage measurements from a signal that consists of a sine wave oscillating at 1,000 Hz. If these 128 samples are number-crunched by an FFT, the result is 64 frequency domain data points or bins. Since we sampled at 4,000 Hz, the maximum frequency that can be accurately acquired is 2,000 Hz; since a single 1,000 Hz signal was present in the source, then bin number 32 of the output data will hold a numeric value that is larger than all of the other bins.

There are other considerations that have been overlooked — such as converting the data in the bins to usable power spectrum data (measured in dB) and using filters on the source data — but these items are beyond the scope of this article.

Now that we have access to frequency domain data and can detect which note is being whistled, all that is left to do is write an application that detects when a particular note (or a note within a specific range) has been held for a second or so and respond accordingly. A Windows application can be downloaded (again, from **www.nuts volts.com**) that allows the user to set up these conditions and respond in a number of ways. (A screen shot of the program can be seen in Figure 5. Also, as mentioned earlier, source code for an example program that shows how to access the A/D, DAC, relays, and digital I/O lines is available for download.)

Conclusion

There is a considerable amount of reading material available online (**www.dlpdesign.com/pub.shtml**) for those wanting to become familiar with FTDI's USB chips and drivers.

FTDI's USB ICs simplify the task of designing a new product utilizing the increasingly popular USB interface and the FT2232C builds upon that legacy by offering a configurable, two-channel version of their existing product line. FTDI's USB drivers are quite mature (i.e., well debugged) and are available for several operating systems.

Since the drivers are provided royalty free and a micro may not even be required for your application, it has never been easier to hit the ground running with your new USB-based product design. Clearly, USB has a strong hold on the PC market and will remain available for the foreseeable future. Personally, I can't imagine using any other interface! **NV**

by Al Williams

Remote Temp Logger

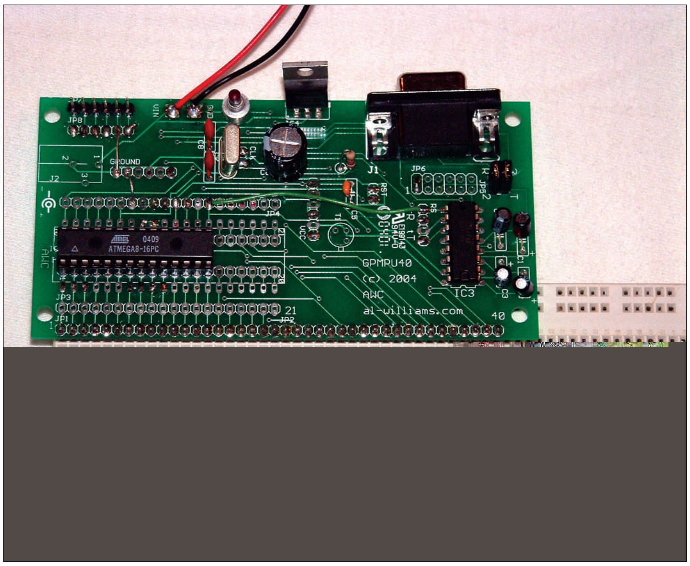
Reach Out and C Your Data

One thing that always strikes me about human technology is its audacity. Think about the public phone system. Imagine a system that connects virtually every location in the country (and nearly every location in the world) with wires. It boggles the mind to contemplate how much wire the entire system must encompass. From our point of view, this wiring makes a tempting infrastructure for data collection. After all, where do you need to collect data where there isn't a phone connection? Even places that don't have traditional land lines now often have cellular or satellite phone connections.

Recently, I needed to acquire some temperature data from multiple remote locations and decided to avail myself of the phone system. For the data acquisition unit, I decided to use an Atmel ATmega 8. This processor has plenty of horsepower for the task and a high performance A/D converter. More importantly, the processor supports the free GNU C compiler and has fantastic library support. Unlike some processors that have a flaky, "small C" compiler, the Atmel part allows you to use GNU C (gcc), which is a full featured, powerful compiler — the same compiler used to build Linux and a host of other tools. The GNU C compiler and tools are available for Linux or Windows and include simulated debugging tools.

As a consultant, one of the problems I face is that different problems often require different solutions — one processor certainly doesn't fit every situation. This led me to design a special PC board — the GPMPU40 — that helps me utilize the best processor for a particular solution (see Figure 1). I built my temperature monitor using the PC board, although you can certainly duplicate it yourself from the schematic in Figure 2. The board contains a footprint that can hold any DIP processor of 40 pins or less. It also contains an RS232 converter, a power supply, reset circuitry, and a clock circuit. On the edge are 40 pins that connect to the processor and allow you to connect the board to a solderless breadboard or other circuitry.

Figure 1. The GPMPU40 PCB can hold a variety of processors. Photo courtesy of Patrick Williams.



Temperature Monitor Design

The hardware is fairly simple. An Atmel ATmega 8 combined with a 10 MHz (or 12 MHz) crystal, an RS232 converter, and the usual auxiliary circuits comprise the central processor. A temperature sensor (an LM34) reads the temperature in a convenient format. The output of this handy IC is a voltage where each degree Fahrenheit corresponds to 10 mV.

The Atmel part has six 10-bit A/D converter channels (although two of them only resolve with eight bits of accuracy). Luckily, the converter can use a reference voltage other than 5 V. After all, with 10 mV/degree, 5 V is 500 degrees — way out of any useful range. However, the part can use an external reference, a 5 V reference, or an internal 2.56 V reference. The 2.56 V reference works well, since this corresponds to about four counts per degree. Of course, the top range is still 256 degrees — much too high. You could use an external reference if you wanted better resolution over a more realistic range.

The RS232 port connects to a standard modem. (I used an old US Robotics Sportster that I had from an old project.) The software reads a temperature every second (it actually averages several samples) and tracks the minimum and maximum temperature recorded.

An interrupt generated from the system clock allows the software to maintain a real time clock. This lets the device recognize when a second has passed and also allows it to time stamp the high and low recorded data.

When the system detects a carrier from the modem, it begins sending data to the remote terminal (see Figure 3). In addition, the remote terminal can set the time or reset the temperature statistics.

About the GPMPU40

If you duplicate the circuit without the GPMPU40 PC

board, you'll also need an Atmel programmer. (You can often use a simple cable to your printer port.) However, the kit (see Resources) contains an ATmega 8 chip that has a special boot loader. This allows you to connect a PC to the board's serial port and download a program directly to the chip with no programmer. This makes development very easy and requires no extra hardware.

However, the serial port is also used for a connection to the modem. This leads to a problem: the PC is a DTE (Data Terminal Equipment) device and expects to talk to a DCE (Data Communication Device). However, a modem is a DCE device and thus expects to talk to a DTE device. That means the monitor should be DCE to talk to a PC and DTE to talk to the modem. One answer is to utilize a cross cable (or null modem) that crosses pins 2 and 3 of the RS232 connection. If you wire the data monitor as DTE, for example, you'd use a straight cable for the modem and the cross cable when talking to the PC. Of course, you could wire the data monitor as DCE and reverse the cable setup, if you prefer.

However, one feature of the GPMPU40 board is a special jumper that allows you switch between DCE and DTE configurations on pin 2 and 3. By setting this up with jumpers, you can switch at will between the two configurations. When the jumpers are parallel with the long edge of the board, the device is able to talk to a PC with a straight cable. Placing the jumpers parallel to the short edge of the board enables the board to communicate with a modem.

The board also has a special set of holes that allow

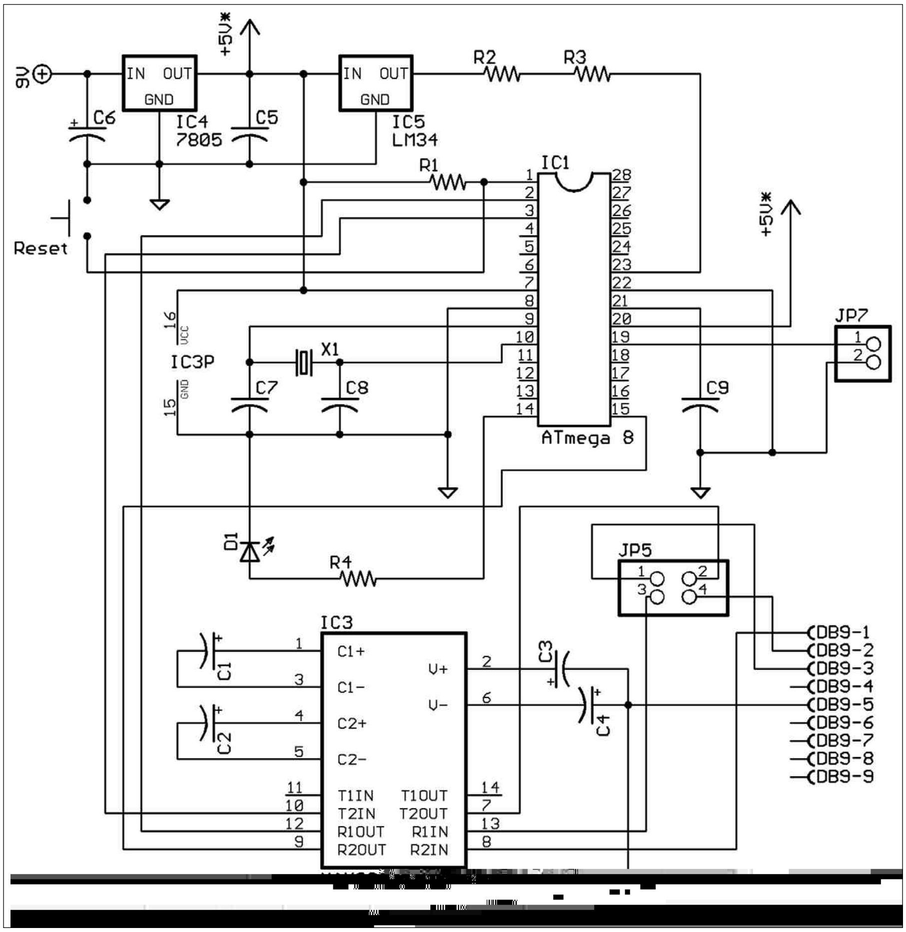


Figure 2. The temperature monitor's schematic.

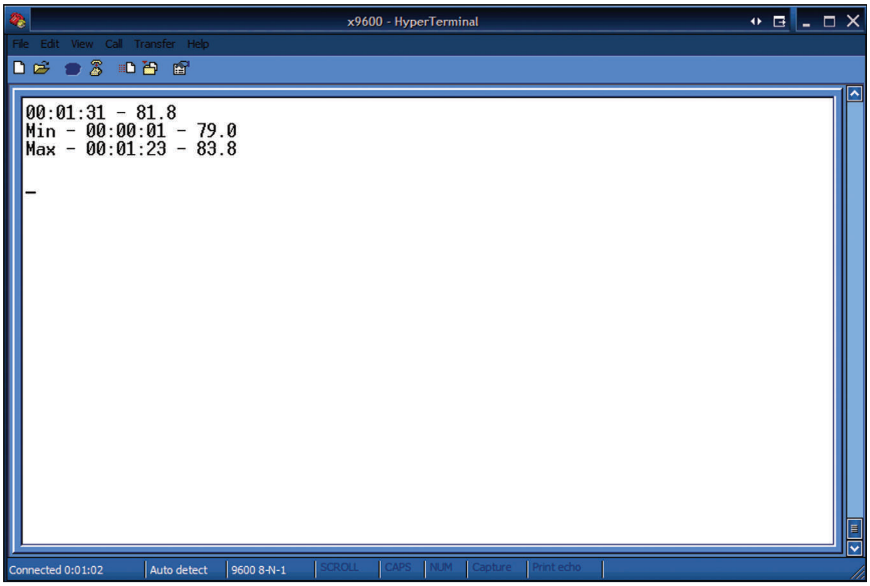


Figure 3. The temperature monitor in action.

you to connect other DB9 pins to the MAX232 level converter IC. In this case, a jumper connects pin 1 (carrier detect) to the MAX232's receiver so that the processor can detect an incoming phone call.

Using gcc

The GNU C compiler is a pleasure to use. If you download the Windows distribution, it includes Cygwin (which makes Windows more like Linux) and an editor that you can use as an integrated development environment. However, I just use the command line along with a standard make file.

To use the make file, I simply copy a standard file to my project directory (named makefile, of course). There are only two lines you have to change in most cases:

TARGET = nvtemp

SRC += app4uart.c app4adc.c rtc.c

The first line names the project (and implies that there is a file named nvtemp.c). The second line names additional files you want compiled. At that point, you simply issue the make command to compile the program. Assuming there are no errors, you can use "make program" to start the programmer to download the code to the chip.

Of course, you do have to customize the template one time to tell it, for example, the COM port you are using for the programmer, but that shouldn't change very often.

It is possible to debug your gcc programs using the Atmel simulator under Windows or using gdb or Insight (a graphical version of gdb) on Windows or Linux (see Figure 4). In any case, you can see the code as C source code and refer to variables by name. Of course, the debugging is with a software simulator. You aren't actually debugging on the chip. However, once you have the program working on the simulator, a few well-placed printf statements will usually help you track down any errant code you have left.

Code Highlights

All of the code is available online at the *Nuts & Volts* website. There are four source files:

nvtemp.c — The main file.
app4adc.c — The file that controls the A/D converter.
app4uart.c — The file that controls the serial port.
rtc.c — The real time clock code.

If you browse the file, you'll see that the program is "real" C. You don't have to shortchange your programming style because of a half-baked compiler. For example, consider the structure that holds the temperature statistics:

```
struct temprec
{
   unsigned t;
   unsigned hour;
   unsigned min;
   unsigned sec;
} min, max, temp;
```

Parts List

R1	10K 1/4 W
R2, R3	1K 1/4 W
R4	470 Ω 1/4 W
C1-C4	1 µF 16V
C5, C9	0.1 µF 16V
C6	330 µF 25V
C7, C8	15 pF
D1	LED (optional; if omitted, omit R4)
IC1	Atmel ATmega 8, 16 MHz version
IC3	MAX232 (if using MAX232A, replace C1-C4 with 0.1 µF capacitors)
IC4	LM7805
IC5	LM34 (for Celsius use LM35)
DB9	DB9 connector (for PCB, female right angle short reach variety)
X1	10 MHz crystal (or 12 MHz)
JP5	2 x 2 header with shunts
JP7	2 x 1 header with shunt (shunt on for programming mode)
RESET	Momentary contact SPST push button

Note: Some parts labeled on board are not used (e.g., IC2).

Thanks to the code in app4uart.c, you can even connect the compiler's standard I/O to the ATmega's serial port:

```
UartInit(BAUD_9600);
UartSetStdio();
printf("Hello Nuts & Volts\n");
```

Of course, printf and scanf are not always the most efficient ways to do things, but they are sure handy in many cases and are also good for debugging your code. It is very handy to use C to aggregate functions into libraries.

For example, rtc.c has functions to support a real time clock. The rtc_init function sets the clock registers so that the processor divides the system clock by eight and uses it as a counter. When the counter register overflows (256 counts), an interrupt occurs.

The problem here is that the main clock is 1.25 MHz (800 nS), so the interrupt period will be 204.8 µS — not handy for keeping real time. The solution is to add an offset to the timer on each interrupt to advance it 4.8 µS. This causes each timer interrupt to fire at 200 µS, a much more pleasant number.

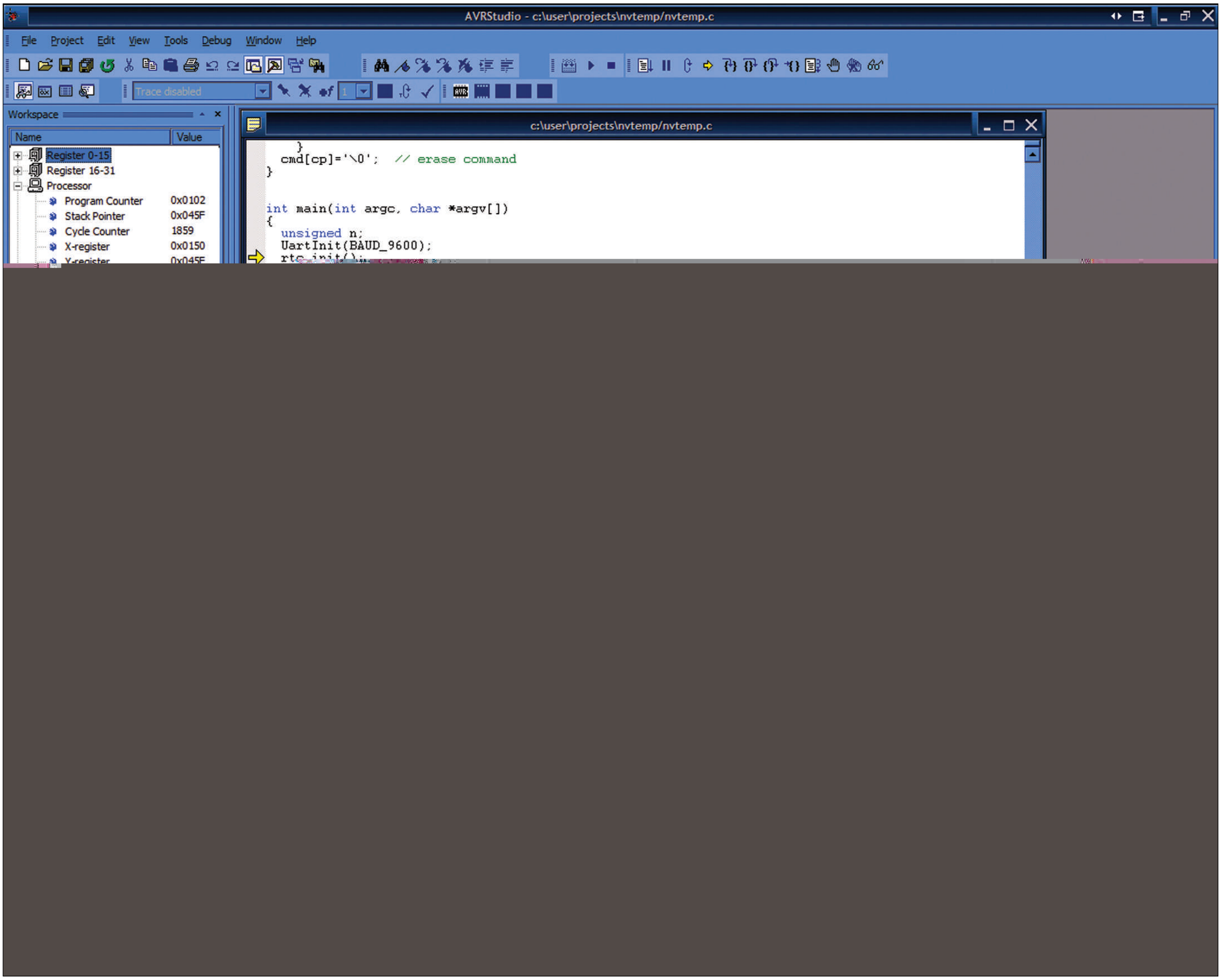
Since the variables that hold the clock count change within an interrupt routine, the rtc.h file marks them as volatile. That prevents the compiler from making optimizations that assume the variables don't change unexpectedly.

Writing an interrupt handler with gcc is very simple. Here's an excerpt from the timer interrupt code:

```
INTERRUPT(SIG_OVERFLOW0)
{
   . . .
}
```

Using the INTERRUPT keyword causes the compiler to

Figure 4. Debugging C code with AVR Studio.



generate the correct code (it saves the interrupt context, in other words). It also installs the handler. The only problem is that the compiler can't easily catch an error in the function name. If I had changed SIG_OVERFLOW0 to, say, SIGOVERFLOW0, the compiler would not complain, but the code would not work, since that isn't the name of an interrupt.

The app4adc file provides a clean interface to the A/D converter. When the program wants to average a few samples, it simply executes this code:

```
// warning: maximum value of adc_convert*AVGCOUNT
// must fit in unsigned int
for (i=0,raw=0; i<AVGCOUNT; i++)
     raw += adc_convert(0);
raw /= AVGCOUNT;                  // average
```

The compiler can generate code to read (and write) the processor's I/O ports. For example, the program uses this macro to test the carrier detect line from the modem:

```
#define DCD ((PINB & 2)!=2)
```

PINB represents the inputs on port B. PORTB represents the outputs and DDRB is the data direction bits.

Improvements

One issue with the data monitor is the way it initializes the modem. To allow the modem to operate properly, the program must use a particular initialization string. The idea is to prevent the modem from sending any data on its own and to have it ignore RTS/CTS handshaking. For my modem, the string is:

```
#define MODEMSTRING "ATV0E0Q1&C1&R1&H0S0=1\r"
```

I also wanted the modem to answer in one ring (the S0=1 part of the string). The board waits a second on power up and then sends the string to the modem. However, if the modem turns off and then back on, it may not power up with the correct defaults.

Many modems have a nonvolatile memory that you can use to save the default state. Changing the modem's default state is probably the best answer. Barring that, it wouldn't be hard to have the program reinitialize the modem every 10 minutes or so (as long as the modem is not already connected). If this happens too often, it might cause missed calls, though.

I've even built similar systems that had a FET that could turn the modem off and on so the program could periodically reset the modem. You could also use a modem specifically for embedded systems like the ones from Cermetek. These often have a way you can reset them remotely.

It would be very easy to add more temperature sensors to the device. (There are five more A/D channels on the chip, three of which have 10-bit resolution.) An LCD showing the current statistics locally would be nice, too. You could even convert to Celsius (or use an LM35 and convert to Fahrenheit).

Remember, a modem can dial out, too. It would be interesting to have the modem dial a pager when the temperature exceeds some limit.

One nice thing about the software in C is that any of these changes would be simple to make, since the subroutines encapsulate all of the difficult tasks — like keeping a real time clock or dealing directly with the analog hardware. **NV**

Resources

Part Sources
For your convenience, the author has made available blank boards, as well as complete kits for this project. See **www.awce.com/nvavr.htm**

Software Sources
You can download the GNU C compiler, as well as related tools for Windows, from **www.avrfreaks.net** If you prefer Linux, download from **http://cdk4avr.sourceforge.net**

You can download the complete C code for this project from the *Nuts & Volts* website (**www.nutsvolts.com**).

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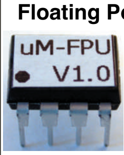

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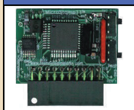
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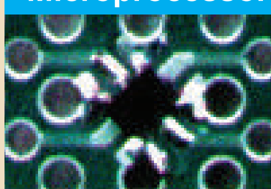

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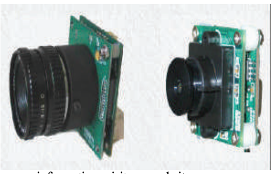

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Designing a CIRCUIT BOARD

by Jeff Johnson

Why would I want to concentrate on designing a circuit board that is a piece of cake to build? Isn't that for the manufacturer to worry about? When they have a list of things to do, they just make the next board in line, right? Well, yes and no. You see, there are small, behind the scenes decisions made every day. Some boards are put at the top of the "to do" list and some are put at the bottom. Even if you aren't making a microwave communications array for NASA's next exploratory rover, someone else is. While your board might not cause problems in the shop, you still want to make sure your project stays on schedule while there is a redo on someone else's.

In this article, I'll talk about a typical two-sided board and some of the things you can do to make it easier to manufacture. Some like to call it DFM — Designed For Manufacturing. I like to call it designing a "big, dumb board": big holes, big traces, big pads — any dummy could make it. While I won't be discussing any specifics about a multi-layer board (they already have a complex design by default), many of the same principles apply.

When reading the design rules specified by your manufacturer, remember that these are the maximums, not guides. Just as you wouldn't test the 60-0 MPH stop time on your car at every light, don't push the manufacturer to the limit with your design if you don't have to.

You have direct control over three steps of the circuit board making process: 1) drilling, 2) imaging, and 3) screening. In drilling, we'll discuss just that — drilling — more specifically, hole sizes. Imaging will include resist imaging, plating, and etching. Screening is the white character screen that makes your board look so professional.

Drilling

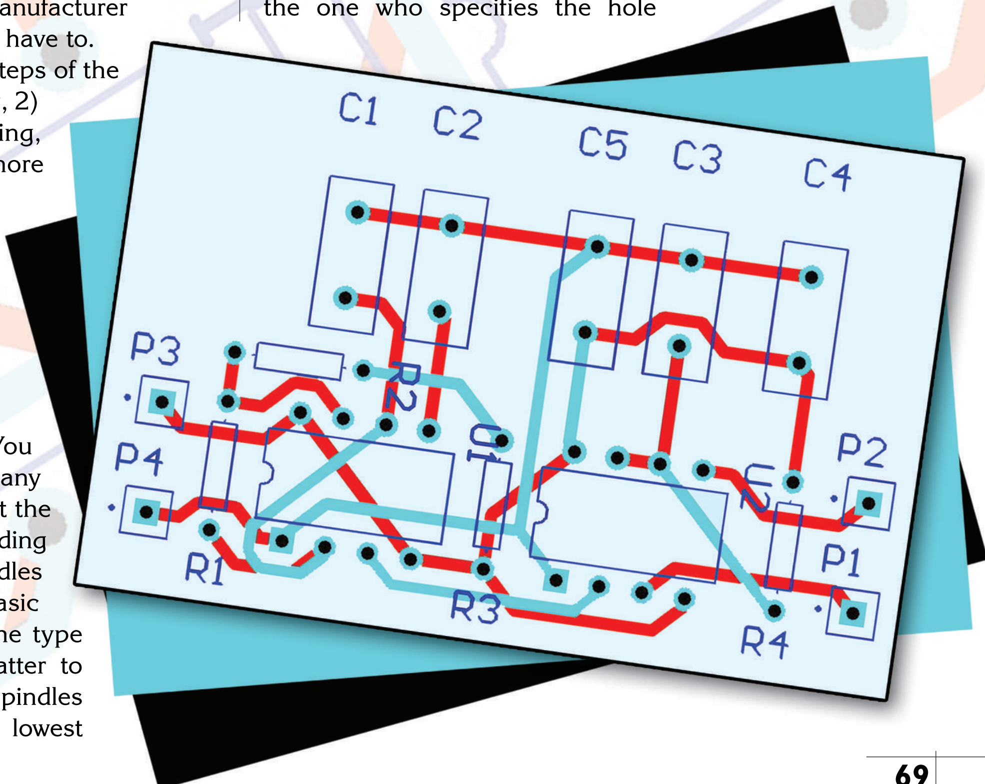
Drilling is pretty self-explanatory. You are poking holes in copper. What many people probably don't know is just what the capabilities and limitations are regarding typical circuit board drills. The drill spindles are very unique and come in two basic styles: ball bearing and air bearing. The type that your manufacturer has won't matter to you. Simply understand that these spindles have high end speed ranges. Their lowest speed is either 14K or 20K RPM — depending on whether they are air bearing or ball bearing — and the upper range is from 80K to 120K. To put that into perspective, your car's engine probably red lines at about 6,000 RPM.

Don't specify too small or too large of a hole.

To drill a .250" hole, the ideal speed would need to be about 7,500 RPM. This is not possible, so the minimum speed is set and drill bits dull fast. Large bits are good for about 1/4 the number of holes as smaller sizes. At the other end of the scale, you probably don't want to specify a hole that is smaller than about .028" or so. Holes as small as .001" are possible in some of the more advanced shops, but .028" seems to be a "magic" number. Any smaller than this and anything that can go wrong, will. Namely, small bits break more often — much more often. Specifying a .008 inch hole is a sure fire way to slow things down. Try to keep component hole sizes in the .030's and .040's and mounting holes around .125". Most manufacturers would probably prefer to keep the hole size .250" or less.

Don't make 14 different hole sizes.

While we are talking about holes, you are the one who specifies the hole



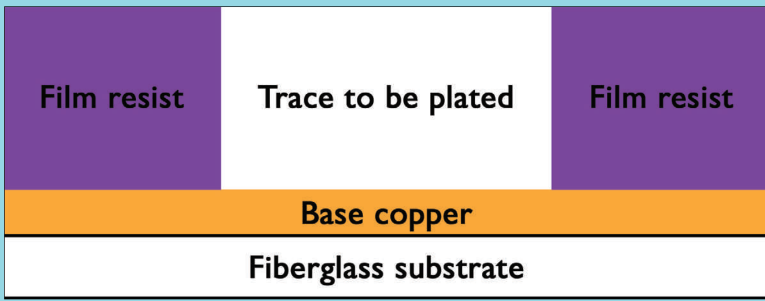


Illustration showing cross section of film after developing.

sizes. Many CAD/CAM programs will output a drill file that you might send to the manufacturer without even looking at it and the hole sizes are included in that file. It can be large and intimidating, but it is really quite simple. It is a text file and, basically, the header gives the drill sizes. Following that is the X,Y coordinate of each hole. By looking at the header, you can see how many different hole sizes there are and what they are.

If you see many hole sizes that are similar (.034, .036, .039), consolidate them into the larger hole size. If you are worried about accuracy, remember that the manufacturer will "bump" this size up .005" or .006" anyway to account for the plating that occurs inside the hole. Since plating varies across the panel, so will the hole sizes (by .001" or so). If you don't feel comfortable manipulating your drill file yourself, tell your manufacturer it is okay for them to do it.

Imaging

Your standard two-sided circuit board will go through many standard steps during its construction. After drilling, the holes will be deposited or coated with a small amount of copper. Then they will be imaged. After that, they will be plated, building the traces up and making the copper in the holes thicker. Next, they are etched, removing the excess copper and leaving your traces. Then they will have the solder mask (green) and character (white labeling) silk screened on. Finally, they go to routing and the individual boards are cut out of the panel. There are some more steps and this is simplified, but this gives us a good base of understanding.

Don't specify too small of a trace.

The entire imaging and plating area is a group of two- and three-dimensional processes that come together to make a product that was designed with two dimensions in mind. To a CAD program, that trace is a line that is X-number of inches wide. To a circuit board manufacturer, that is a trace that has to be built up and etched away. It has to be made tall enough and has to start out wide enough to account for etch back and light undercutting. It has to be built to the specified height in plating. Also, the ratio of how wide it is to how tall it is must be enough to withstand all of the variations that can come into play.

The first part of creating the traces is the actual imaging process. First, the board is laminated with a photo sensitive film. A two dimensional photo image is laid on the board and the image is exposed onto the film. The film is then developed, essentially washing away what will be the circuit and leaving "grooves" to be plated up. This is the first three-dimensional process that can create a headache with a thin line. If any light creeps under the edge of the photo, it will reduce the size of the trace. If the trace is thin to begin with, it may disappear all together. The developed image must be a three-dimensional "canyon" that has straight walls and matches the photo in size and shape when viewed from the top.

These grooves are deep. They are so deep that you can actually run your finger across the board and feel the image. This is no accident. The boards are going to go through some harsh environments and you want your plating resist to survive. The resist also has to be thicker than — or at least as thick as — the plating will be. It is going to be the "mold" that contains and shapes the electrical plating.

After imaging, the boards are electrically plated. The little canyons are filled with copper during the plating process. The holes also get plated at the same time, making them strong enough to withstand stuffing a component

into them, melting solder into it, and even removing a component, if necessary. On top of the copper, an etch resist is plated — either tin or tin/lead, depending on the shop and what kind of finish the board will have. After that, the film is stripped off and it is on to etching.

Etching is another three-dimensional process necessary to produce a two-dimensional result. Not only does the copper around a trace get etched away, but so does the side of a trace. While a trace may only be .002” tall, it can easily lose as much as .002” off both sides at its base. That means that, if you had a trace that was only .004” wide, the base could be completely etched away and the trace would physically lift from the panel.

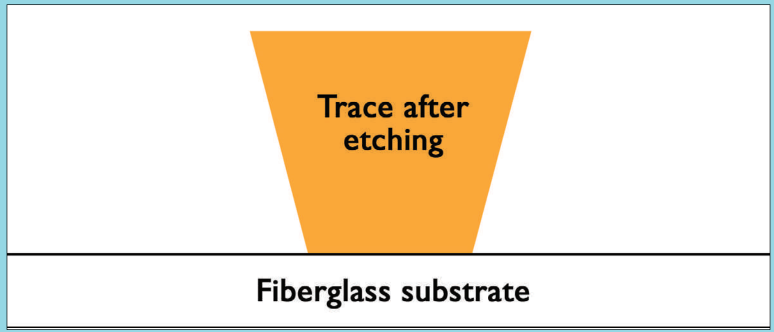


Illustration showing cross section of trace after etching.

Thin traces take special handling and special handling can drop you a couple of notches on the “to do” list. Consider keeping your trace size to a minimum of .010”. If you have the room, .030” is a no-brainer for the shop. A .030” trace will survive if every process in the shop has a problem. A .010” trace will survive as long as everything does what it is supposed to. A .005” trace will only survive if everything goes just right. Smaller traces can be done if necessary, but that hardly qualifies as big or dumb.

Make sure your pad is big enough.

The same photo process that made the traces will also make the pads at the same time. The pads are what will actually be used to line up the board. If you get a board that is aligned off to one side, many people would say the holes were drilled wrong when, in actuality, it was the pads and traces that were put in the wrong place.

The film stretches and shrinks with changes in heat and humidity. If you specify a pad size that is .012” bigger than the hole, that is a small pad. If the manufacturer steps the hole size up .006”, you now have .006” left over. That is a .003” annular ring — the space between the edge of the hole and the edge of the pad. If the drill was off by as little as .001” and the film stretched by as little as .002” across an 18” section, you would suddenly not have any pad left along one side of a hole. That is called “breakout” and it happens enough with close-tolerance boards that there is a specification as to how much is allowed.

Make sure your pads are .035” bigger than the holes. That may sound like a lot, but remember that the hole size will be stepped up .005” to .006”. Subtract the hole size from the pad size, remove the .005” that was stepped up, divide by two to get the annular ring size, and you will be left with a .015” annular ring. Grab a pair of calipers and take a look at what .015” looks like. It isn’t a lot.

If your board has through-plated holes, make sure they are all plated through.

Sometimes, someone will only need some of their holes plated through and that is fine. Where it runs into trouble, though, is when you have holes that aren’t plated through and have a pad on the bottom side for a component without a matching pad on the top side. Light travels down from the top of the board when it is exposed with the circuit. It goes through the hole without a pad and hits the back side of the pad on the bottom of the board. That makes a “dot” the size of the hole that will literally float around in developing.

These “dots” like to land back on the board and attach themselves where there should be a continuous trace. That means there is no plating and a break in the trace. Again, this is a problem that is usually found late in the process — well after it is too late to fix it — and another redo is needed.

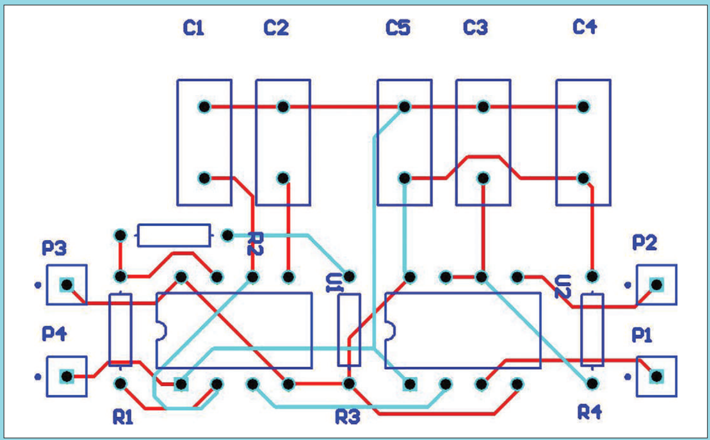


Illustration showing 5 mil annular ring, 10 mil traces, and 40 mil character.

Through–plated holes make soldering easier. The solder will “wick” from the bottom side to the top and you will get a stronger connection. You can tell at a glance if you have a good solder joint by looking at the top of the board. Your board will have a truly professional look. It is one of those things that you can’t put your finger on, but it makes one project look better than another. In addition, your board will be easier to manufacture and you have a better chance of getting it on time. Just simply place a pad on top every place you have a pad on the bottom and the holes will be plated-through.

Check your design for errors (opens).

Make sure you zoom in *and* zoom out on your design while giving it the final once-over. While a space or clearance might look good on the screen, it can be impractical in real life. Keep your spaces to .010” or more and be realistic about physical limitations. I have seen where someone placed mounting holes .010” away from the edge of the board. It looked good on the screen until you zoomed out. When you looked at the board actual size, the .010” couldn’t be accurately displayed on the screen. If this sliver of material had survived, it would have been brittle and flimsy, not good for a mounting hole. While you are at it, print your circuit out on paper. If your printer is having trouble accurately displaying the image, your job probably won’t be classified as a piece of cake.

While routing your traces, make sure you have the “snap to” function turned on. This will ensure that all of your traces actually terminate into pads and that two joining traces actually connect together. Sometimes, if you zoom in to a pair of traces, you will see where they don’t actually connect. The same thing happens where a trace meets a pad. If you don’t catch it before the film is printed, it might not be caught before the board is being manufactured. All too often, these errors are caught in Quality Control, the last step before a board is sent out. That means a redo and a long wait on a board that should have been done already.

Be realistic about your silk screen characters.

One last area that seems to be often overlooked and consistently specified incorrectly is the character silk screen. The process that you might have used to make T-shirts in art class back at summer camp is almost the same process that is used to put the white labeling (the character screen) on your board. First, a film is exposed and developed with the image of your characters. Next, it is fixed to the silk screen. Then, a squeegee is used to push ink through the screen and film and onto your board. If the size of the opening is too small, the ink will dry in the screen and won’t go through. It doesn’t take long — only a few seconds. If you have ever gotten a board with skips in the character, that is what happened.

You will want to specify an aperture width of .010” to .012”. That means that, while your characters will possibly survive if they are as little as .040” or .050”, you will probably want them to be .070” tall or taller. When you print your circuit, play around with a pair of calipers and see how tall you can make the characters and still have the board look good.

In Conclusion

You have direct control over your design and, therefore, you are responsible for how easy your board is to build. Many times, what could be a “big, dumb board” is turned into a “nightmare board” just because it is ill–designed. Follow these rules and your board should be a piece of cake to build:

1. Keep your hole sizes in the .030” to .040” range. Keep mounting holes .250” or less.

2. Specify six or fewer hole sizes.

3. Make your traces at least .030” if possible.

4. Make your pads at least .035” bigger than the hole size.

5. If some holes are plated-through, they all should be plated–through.

6. Make your silk screen characters .070” tall or taller.

7. Print your circuit on paper and see what it actually looks like.

If you have some tolerances that are tighter than others, let your shop know. If they know that a board is just there to connect electricity, instead of a microwave board with onboard capacitors, they can widen traces and increase pad size as necessary. If you can, arrange to take a tour of your circuit printing shop. I guarantee that you will be surprised as to what actually happens during the manufacture of a circuit board. NV

(continued from Page 34)

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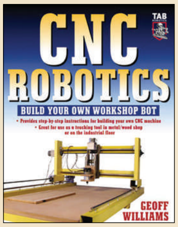

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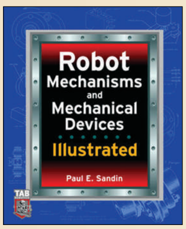

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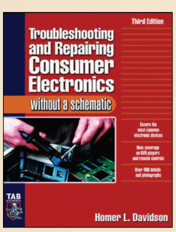

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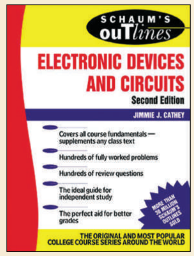

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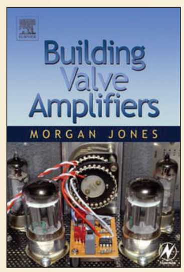

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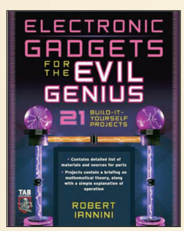

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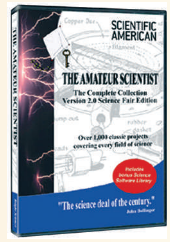

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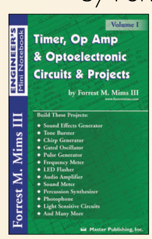

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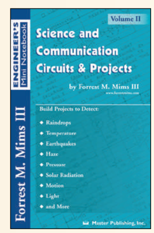

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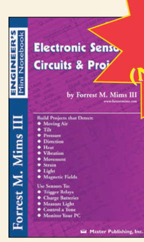

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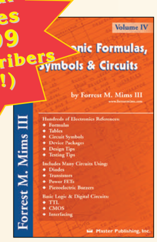

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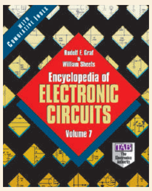

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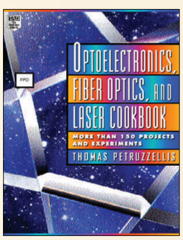

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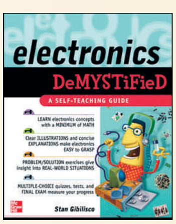

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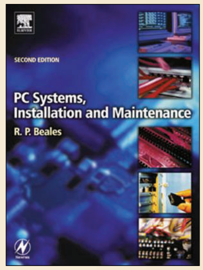

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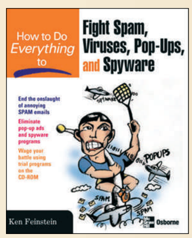

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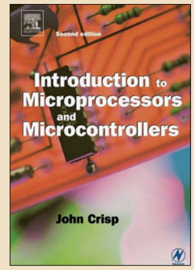

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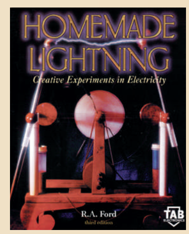

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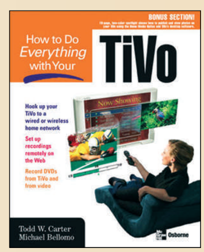

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Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

I^2C Again — and the Case for Continuous Improvement

George Lucas says (and he may have been quoting someone else), "Movies are never 'done' — they're simply abandoned." Funny, that's how I feel about my BASIC Stamp programs, even the ones that work really well.

I grew up — figuratively and literally — in a large corporation: the Toro Company. It was my first job out of the US Air Force and I ended up staying with Toro for about 14 (fantastic) years. I was lucky to have a lot of great mentors and the lessons I learned at Toro stay with me today. One of Toro's core philosophies that I hold dear is that of continuous improvement. If something (a product, for example) can be made better, then the efforts to that end are well spent.

I get the idea that a lot of BASIC Stamp users have discovered the fun and utility of the myriad (over 1,000) of I^2C devices available today — even those users that don't have the BS2p or BS2pe with the built-in **I2COUT** and **I2CIN** instructions. A couple of years ago, I wrote a column with manual (bit-banged) I^2C code that would work on the BS2, BS2e, and BS2sx. Well, that was a while ago and the PBASIC 2 and the BASIC Stamp compiler have been upgraded since then, so it just seems to make sense to revisit those programs to see if they could be improved. Indeed, they can and that's just what we're going to work with this month.

Our purpose, then, is to do a very quick review of I^2C and the implementation we can use easily with the BASIC Stamp 2 family and then work through a few example chips so that we aren't fooled into thinking that our code doesn't stand up. I mention this because I get lots of "This just isn't possible ..." Emails when that is simply not the case (and I always send back proof of my position). Sometimes, we have to look a bit beyond what we perceive to be the "rules" and then bend them.

Quickie I^2C Review

Before I start, let me beg you, cajole you, plead with you — on my knees, if necessary — to download the I^2C specification from Philips and at least give it a glance. That goes for any I^2C devices that you want to use, as well. I think you'll find after working through a few parts here that any component you choose can be handled with just a tiny bit of custom code. You'll see this in the examples.

Okay, now for the essentials. The I^2C protocol is a two-wire (synchronous) serial protocol that has a master and one or more slave devices. Yes, there is a provision in the specification for multiple masters, but that is beyond the scope of our experiments — and we're not likely to need multiple masters in a small microcontroller system, anyway. The master generates the synchronous clock for all attached devices. Depending on what is happening at any given moment, any device on the bus might be a transmitter or a receiver. Data is sent back and forth a byte (eight bits) at a time, with the receiving device creating an acknowledge bit after each received byte.

The two wires used for the I^2C bus are called SDA (serial data) and SCL (serial clock). These lines are pulled to Vdd through 4.7K resistors (typical). For a device to generate a "0" on either bus line, that line is

Figure 1. I^2C start and stop signaling.

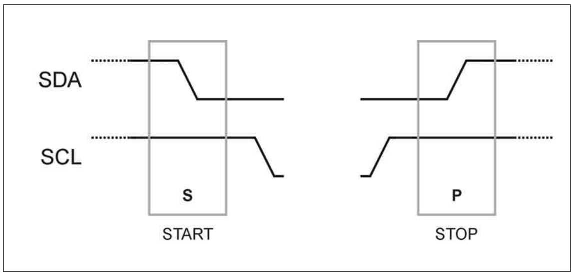
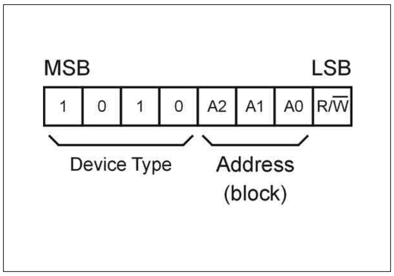


Figure 2. I^2C slave address byte.



pulled low. To create a "1" the bus pin is set to a Hi-Z (input) state and the pull-up takes care of the rest.

We're going to cheat a bit, though, because the BS2 family has built-in commands for two-wire synchronous serial communication —**SHIFTOUT** and **SHIFTIN** — and these instructions nicely fulfill the byte and bit transmission and reception requirements of I^2C. Both of these instructions drive the bus high to generate a "1" bit. In theory, this could create a problem if one of the other devices on the bus is shorted to ground. I've never had such a problem, though, probably because the bit rate of **SHIFTOUT** and **SHIFTIN** is pretty swift and the pin is left low when the function is finished. Even so, if you're concerned, you could always place 220 Ω resistors inline with the SDA and SCL pins.

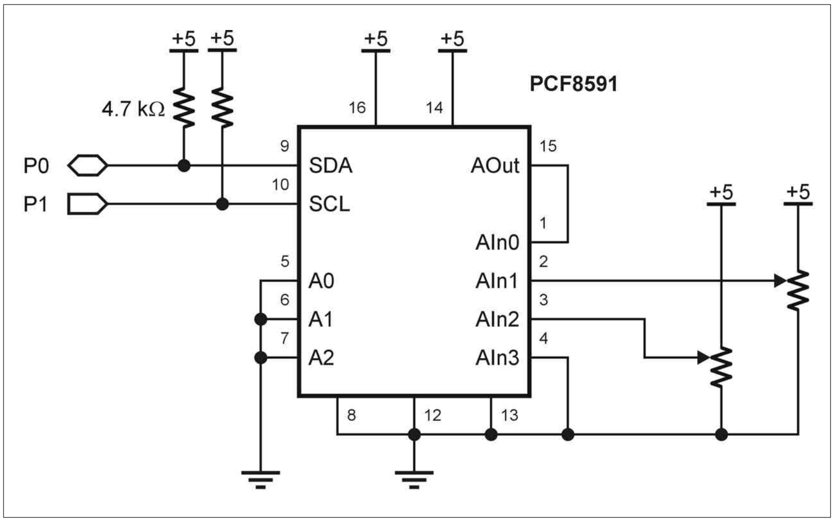


Figure 3. PCF8591.

Communication on the I^2C bus begins with the master generating a "Start" condition. A Start is defined as bringing SDA low while SCL is high (see Figure 1). The master then transmits the slave address of the device it wishes to connect to. We'll be using seven-bit addressing (Figure 2) where the upper seven bits of the slave address byte contain the device type and address and bit zero holds the data direction: "0" indicates a device write and "1" indicates a device read.

What follows the slave address will vary, depending on the device and the type of request. On many devices, we'll have one or two address bytes, followed by the data byte(s) to write to or read from the device. The transmission is terminated with a "Stop" condition; this is defined as bringing the SDA line from low to high while the SCL line remains high.

Jump Right In, the Water's Warm

In my book, demo code speaks louder than words, so let's just jump right in and discuss the low level code for I^2C communications. From these low level routines, we can communicate with any I^2C device. What we'll do a bit later is create a useful set of higher level routines that will handle most of our requirements. When those don't quite fit, we can build — from these same blocks — custom routines that will handle the special requirements of a given device.

We'll begin — logically — with the Start condition:

```
I2C_Start:
  INPUT SDA
  INPUT SCL
  LOW SDA

Clock_Hold:
  DO : LOOP UNTIL (SCL = 1)
  RETURN
```

The I2C_Start routine allows both bus lines to go high by making the control pins inputs and letting the pull-ups do their thing. Then the SDA line can be pulled low; a Start condition has been generated.

The I^2C specification allows a slave device to indicate that it is not ready by holding the clock line low. This is

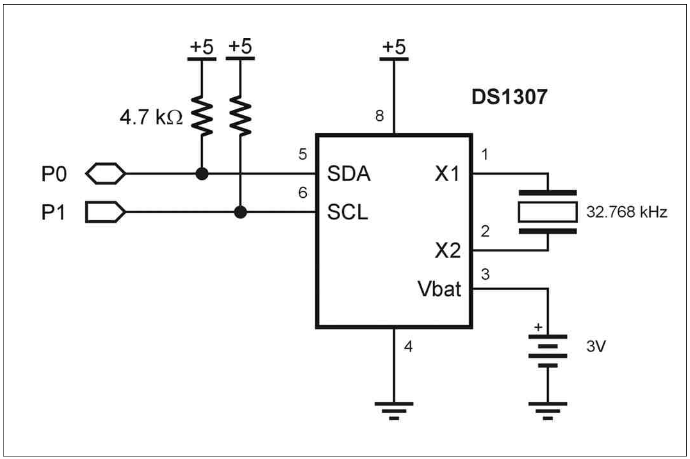


Figure 4. DS1307.

called clock stretching. We can check for this at the section called Clock_Hold. If the SCL line is being held low, the (empty) **DO-LOOP** will run. The only possible danger here is a device that has shorted the SCL line to ground; this would cause the routine to hang indefinitely. We could increment a variable in the middle of the **DO-LOOP** and check for a timeout value if this becomes a problem, but —again — this is something I've never experienced in any of my I^{2}C experiments, so I don't think it's worth doing, except in a situation where a bus hang could create serious problems for the application.

After the Start condition, the master sends the address of the intended slave device to the bus. This is a single-byte transmission and is handled with the I2C_TX_Byte routine.

```
I2C_TX_Byte:
  SHIFTOUT SDA, SCL, MSBFIRST, [i2cWork\8]
  SHIFTIN SDA, SCL, MSBPRE, [i2cAck\1]
  RETURN
```

We can see how easy this is using **SHIFTOUT** to send out byte, MSB first. **SHIFTIN** handles picking the acknowledge bit from the bus. The \1 parameter is used with **SHIFTIN** so that we only produce one clock pulse for the acknowledge bit.

The complimentary routine, of course, is I2C_RX_Byte; its job is to receive a byte sent by the slave device.

```
I2C_RX_Byte_Nak:
  i2cAck = Nak
  GOTO I2C_RX

I2C_RX_Byte:
  i2cAck = Ack

I2C_RX:
  SHIFTIN SDA, SCL, MSBPRE, [i2cWork\8]
  SHIFTOUT SDA, SCL, LSBFIRST, [i2cAck\1]
  RETURN
```

This routine actually has two separate entry points: I2C_RX_Byte and I2C_RX_Byte_Nak. Why? The reason is that the master will indicate that it's requesting the last byte in a "package" by setting the ack bit high (Nak). The rest is as straightforward, as with transmission. **SHIFTIN** handles the reception of the slave data byte and **SHIFTOUT** transmits the acknowledge bit back.

To terminate a transmission, the master generates a Stop condition.

```
I2C_Stop:
  LOW SDA
  INPUT SCL
  INPUT SDA
  RETURN
```

No magic here, either. The SDA line is held low while the SCL line is allowed to be pulled high by the bus pull-up; then the SDA line is released to its bus pull-up.

Okay, then, with these simple subroutines, we can handle communication with any I^{2}C device that uses seven-bit addressing. That said, we can save a lot of redundant code by constructing slightly higher level routines to write to or read from a device. Here's where we need to put in a bit of thought. You see, I^{2}C devices can have zero, one, or two internal address bytes (called the word addresses) — depending on the device function. The PCF8574, for example, has no internal addresses; we simple write to or read from the device I/O pins. The MCP23016, though, has several configuration registers in addition to its I/O, so it uses a single word address byte. If we look at an I^{2}C EEPROM — like the 24LC32 — we'll see that it requires a two-byte word address to get to all of its memory locations.

The BS2p/pe **I2COUT** and **I2CIN** instructions handle these situations with a variable parameter list; we can specify no word address, one byte, or two bytes. In our code for the BS2/BS2e/BS2sx, we'll have to be a bit verbose, but it's not tough and gives us the flexibility to handle multiple I^{2}C devices of different configurations in the same project (a robot, for example).

Let's look at the code for writing a single byte to a given location within an I^{2}C device:

```
Write_Byte:
  GOSUB I2C_Start
  i2cWork = slvAddr & %11111110
  GOSUB I2C_TX_Byte
  IF (i2cAck = Nak) THEN Write_Byte
  IF (addrLen > 0) THEN
    IF (addrLen = 2) THEN
      i2cWork = wrdAddr.BYTE1
      GOSUB I2C_TX_Byte
    ENDIF
    i2cWork = wrdAddr.BYTE0
    GOSUB I2C_TX_Byte
  ENDIF
  i2cWork = i2cData
  GOSUB I2C_TX_Byte
  GOSUB I2C_Stop
  RETURN
```

The routine begins by generating a Start condition and then transmits the device slave address with bit zero of the slave address set to “0” to indicate a write operation. If the slave returns a Nak, the Start is resent. This is called “Acknowledge Polling”; it causes the master to wait until the slave is actually ready for data before sending it.

Next, the routine will send the word address — if required by the device. The number of bytes required for the device word address is sent to the routine in the variable addrLen. For the PCF8574, the value of addrLen would be set to zero. If this was the case, the code would skip over sending the word address byte(s) and transmit the data byte, then generate the Stop condition.

If we were using an MCP23016, though, addrLen would be set to one and the word address (register we want to write to) would be placed in wrdAddr. The low byte (BYTE0) of wrdAddr is sent before the data byte and stop condition. For the 24LC32, addrLen would be set to two. In this case, both bytes of wrdAddr are transmitted: high byte (BYTE1), then low byte (BYTE0).

In an application program with multiple I^{2}C devices — including a PCF8574A with its address bits set to %000 — we could put the Write_Byte routine to use like this:

```
devNum = %000
slvAddr = PCF8574A | (devNum << 1)
addrLen = 0
i2cData = %00001111
GOSUB Write_Byte
```

This would write %00001111 to the I/O pins of the PCF8574A. Okay, now we can write to any location in an I^{2}C device; let’s build a routine that allows us to read data back.

```
Read_Byte:
  GOSUB I2C_Start
  IF (addrLen > 0) THEN
    i2cWork = slvAddr & %11111110
    GOSUB I2C_TX_Byte
    IF (i2cAck = Nak) THEN Read_Byte
    IF (addrLen = 2) THEN
      i2cWork = devAddr.BYTE1
      GOSUB I2C_TX_Byte
    ENDIF
    i2cWork = devAddr.BYTE0
    GOSUB I2C_TX_Byte
    GOSUB I2C_Start
  ENDIF
  i2cWork = slvAddr | %00000001
  GOSUB I2C_TX_Byte
  GOSUB I2C_RX_Byte_Nak
  GOSUB I2C_Stop
  i2cData = i2cWork
  RETURN
```

You’ll notice right off that the Read_Byte routine is a tad more involved than Write_Byte. The reason is this: At the time of use, we probably don’t know what the internal address pointer of the device is sitting on, so this routine sets it manually. This is accomplished by starting what amounts to a write operation to the device and then regenerating another Start condition after the word address is transmitted. Of course, the word address is sent only for those devices that require it. After the address pointer is set (if required), the slave address is sent with bit 0 set to “1” to indicate a read operation. Since this routine only reads one byte — and that byte will be the last — the I2C_RX_Byte_Nak routine is used to retrieve the byte. With the data byte safely in hand, a Stop condition is generated and the work value is placed in i2cData for use by the main program code.

Let’s say we wanted to read the value at location $200 in a 24LC32 (4K EEPROM). Our code would look something like this:

```
devNum = %000
slvAddr = EE24LC32 | (devNum << 1)
addrLen = 2
wrdAddr = $200
GOSUB Read_Byte
DEBUG "Location $200 holds: ", DEC i2cData
```

Again, this code is very verbose. If the only thing we had attached to our BASIC Stamp was a single 24LC32 we

could set devNum, slvAddr, and addrLen as part of the initialization code and not have to worry about them after.

Hopefully, this is all making sense now and some of those data diagrams you find in I^2C device data sheets are becoming easier to understand. Let's have a look at a couple more devices and write some additional routines to make data access simpler.

The first device we'll look at is the PCF8591. This is a nice little four channel A2D converter with a single D2A output. (All channels — in and out — have eight bits of resolution.) When we look at its data sheet, we'll see that writing to the D2A channel requires a control byte before transmitting the analog output level. How do we handle this control byte ahead of our analog level byte? Well, the easiest way — in my opinion — is to tell the Write_Byte routine that we have a single-byte word address and put it in there. What this does for us is send two bytes to the same slave address without creating additional routines. Here's how simple it is to send a value to the analog output channel:

```
addrLen = 1
wrdAddr = EnableD2A | AutoInc
i2cData = aOut
GOSUB Write_Byte
```

The control byte (which is placed in wrdAddr) is set up to enable the D2A output, configure all the analog inputs as single ended, and cause the PCF8591 to increment through them on each read.

Now things rev up a bit: We want to read all four analog input channels in a single operation. For this, we're going to create a new high level subroutine:

```
Read_Analog:
  GOSUB I2C_Start
  i2cWork = slvAddr | %00000001
  GOSUB I2C_TX_Byte
  GOSUB I2C_RX_Byte
  FOR idx = 0 TO 2
    GOSUB I2C_RX_Byte
    aIn(idx) = i2cWork
  NEXT
  GOSUB I2C_RX_Byte_Nak
  aIn(3) = i2cWork
  GOSUB I2C_Stop
  RETURN
```

After generating the Start condition and sending a read-mode slave address, we read back a byte and then throw it away? Why? Well, when you look at the PCF8591 data sheet (hint, hint), you'll see that a channel conversion is actually offset from a byte read. What this means is that the first byte read back is from a previous conversion and

may no longer be valid.

Now that we've got fresh conversions, we can read channels 0–2 with a loop. This works because the I^2C device will automatically increment the internal word address pointer after each read. The work byte used by our low level I^2C routines is transferred into the analog array used by the program. The final channel is read manually with I2C_RX_Byte_Nak as it is the final read in the group.

As you can see, our foundation routines are serving us well and we don't have to write a lot of code to get good use out of I^2C devices. Let's look at one more example before wrapping up. In the previous example, reading all of the analog channels from the PCF8591 is called a "block read." What about a block write? Of course we can do that!

Let's say we want to add a real time-clock to our project and we've already got other I^2C devices. In this case, the DS1307 is a great solution. If we define the clock variables in the order they appear inside the DS1307, we can create a couple of very clean routines for setting or getting the clock data.

First, here's how we would define the clock variables for the DS1307. Note that the order of these variables is critical for the proper operation of our block write and read routines.

```
secs        VAR     Byte
mins        VAR     Byte
hrs         VAR     Byte
day         VAR     Byte
date        VAR     Byte
month       VAR     Byte
year        VAR     Byte
control     VAR     Byte
```

Now, let's create a routine that sets all the clock variables in one fell swoop:

```
Set_Clock:
  GOSUB I2C_Start
  i2cWork = slvAddr & %11111110
  GOSUB I2C_TX_Byte
  IF (i2cAck = Nak) THEN Set_Clock
  i2cWork = 0
  GOSUB I2C_TX_Byte
  FOR idx = 0 TO 7
    i2cWork = secs(idx)
    GOSUB I2C_TX_Byte
  NEXT
  GOSUB I2C_Stop
  RETURN
```

This should look pretty familiar by now. We generate a

Start condition, send the slave address in write mode, and then send the word address. In this case, the word address is manually set to zero because this is the address of the seconds register. Since the internal word address will be incremented after each write, we can use a loop to write the clock variables, using secs as the root of an array.

Remember, the BASIC Stamp memory can be treated as an array even if we don't explicitly declare it as such; this can be very powerful when used carefully. This is the reason that our variables must appear in the order that they do: The BASIC Stamp compiler assigns RAM space by variable size and in the order of declaration.

Let's finish up with a block read of the DS1307:

```
Get_Clock:
  GOSUB I2C_Start
  i2cWork = slvAddr & %11111110
  GOSUB I2C_TX_Byte
  IF (i2cAck = Nak) THEN Get_Clock
  i2cWork = 0
  GOSUB I2C_TX_Byte
  GOSUB I2C_Start
  i2cWork = slvAddr | %00000001
  GOSUB I2C_TX_Byte
  FOR idx = 0 TO 6
    GOSUB I2C_RX_Byte
    secs(idx) = i2cWork
  NEXT
  GOSUB I2C_RX_Byte_Nak
  control = i2cWork
  GOSUB I2C_Stop
  RETURN
```

Again, we begin with the Start condition, transmission of the slave address in write mode, followed by the register address — zero in this case — to point to the seconds register. Then, we resend the slave address in read mode and use a loop to read the first seven clock variables (secs through year). The final variable, control, is read with I2C_RX_Byte_Nak because it is the last byte in the read sequence.

More, More, More ...

Don't worry if this is all not perfectly clear yet. Keep looking at the data sheets and the code examples and, at some point, you will have one of those "Aha!" moments of clarification. Be sure to download the example files because I've included more devices than what we had room to discuss here and I believe that, by examining them, you'll gain more insight into handling I^2C devices with a BASIC Stamp microcontroller.

What's Next?

Those of you who have been around a while will remember that, last December, we created a one-wire serial slave device using the BS1 microcontroller. While simple, using a BS1 module is not the most cost-effective way to do this. Wouldn't it be nice if we could use a $2.00 microcontroller without being forced to use assembly language? Of course it would be — and now we can. Next month, we'll build a serial slave device using the SX micro and a free (can't beat that price) BASIC compiler from Parallax called SX/B.

Until then, Happy Thanksgiving to you and your loved ones — and, as always, Happy Stamping. **NV**

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The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Generalize Versus Specialize

At some time in an engineer's career or in a business' development, a decision about specialization or generalization will occur. This month, we'll discuss and examine various factors and implications of generalization and specialization. Clearly, it's useful to consider the good and bad points of each position well before you face the choice.

Definitions

The rude definition of a generalist is: a jack of all trades and a master of none. Conversely, specialists are people who know more and more about less and less until they know everything about nothing. Obviously, there are many gradations of specialization and generalization.

I should point out that generalization is not simply the absence of specialization. Generalization is an active choice that requires lots of work. There are fewer generalists than specialists for several reasons. First, there aren't many academic programs that provide broad-based training. There are various interdisciplinary undergraduate tracks; however, these are usually considered foundation training for advanced degrees. For example, an interdisciplinary biology/chemistry BA degree is useful for getting into medical school.

Secondly, it is usually assumed that specialization is the natural goal of education. Clearly, no one can know everything about everything. Every person is limited in their ability to absorb information about some number of topics.

So, specialization is a natural assumption. This means that generalization often requires challenging the standard academic pattern. This is rarely easy or simple.

Then there is the mind set of a generalist. It's different. Most young people go to college to get a degree that's useful in getting a job. The generalist goes to college to learn as much as possible about as much as possible. A specific career path may not be an immediate objective.

Decision Time

Unfortunately, many students and engineers specialize without realizing that they are making an important life decision. They get their Masters degrees and then their Ph.D.s and view these as rungs in a ladder, rather than a branch in the road. (A BSEE degree isn't really a specialization. It's more like a vocation.) When a student chooses a Ph.D. advisor — which is usually done upon acceptance to a program — he is really choosing a dissertation topic. This is simply because the advisor is the academic guide and coach for the student. The resulting Ph.D. dissertation often sets the person on a track for life. Few students realize this at the time, though.

Suppose your dissertation is on "Using Autonomous Robots for Landmine Detection." What job will you get after you graduate? If you stay in academic research, you will need money to support your work (publish or perish). You do this with grants. You only get grants if you convince the granting agencies that you have the experience to perform the research. This means that you will probably be able to get money to extend your dissertation topic or something closely related to it, but you probably won't get money to research "Robotic Self-Assembly."

This creates a never-ending cycle. The more experience you have, the more specialized you become and the more likely you will obtain grants in your specialty. Trying to change your specialty jeopardizes your ability to obtain grant money. So, when you choose your dissertation topic, you should ask yourself if this is what you want to do for the rest of your life.

If you take your Ph.D. into an industrial setting, you will be faced with a very similar situation. Quite simply, if the company needs someone for "Robotic Self-Assembly," they aren't likely to choose someone who has all this experience in "Autonomous Robots" and "Landmine Detection." Would you?

Your last common career choice for a Ph.D. is teaching without research. This usually means a small community or state college. This also means relatively low pay and an inability to pursue your research interests because of lack of money for funding.

However, teaching is a very rewarding profession all by itself. What's more, it's actually fairly easy to teach different courses. Teaching at the undergraduate level isn't very specialized.

The Benefits of Specialization

It may seem that I'm anti-

specialization — not so. Instead, I'm trying to identify factors that often seem to be overlooked. Specialization has many benefits.

The first is that, the more you specialize, the more money you make. This is simple supply and demand at work. If someone needs what you have and you're the only one who can supply it, they will be willing to pay a lot. If there are a million people with the same experience, the pay will be much less.

Specialization is a fairly straightforward process. Usually, an academic program is already in place. You can certainly specialize without an advanced degree. This happens all the time in industry. For example, the person who sets up and maintains a unique computer system for 10 to 15 years is a specialist. There are very few others (if any) who have his knowledge and experience. Since he has spent so much of his career (which is typically about 40 years) in this position, he will find it somewhat difficult to work in a different setting.

There is usually some prestige in being a specialist. Either you have an advanced degree and do groundbreaking research or else you are a key person in the company. People will respect your opinion and you will have a great deal of credibility concerning your speciality. This credibility can — and does — carry over to other areas, even though it may not be warranted.

The Problems With Specialization

Probably the biggest problem in any engineering specialty is obsolescence. New procedures and developments are occurring at a staggering rate. Even if you are at the leading edge, someone may develop something that may make all your past efforts outdated.

Consider hybrid circuitry. Twenty years ago, it was the smallest way to package electronics. It required very specialized skills to design and manufacture. They were used extensively in military, space, and other high reliability/space-limited applications. There were all sorts of special equipment and procedures needed for hybrid circuit manufacturing. The specialists in designing the circuits, manufacturing the circuits, and fabricating the equipment needed to manufacture the circuits made a lot of money. Then came surface mount parts.

Nowadays, the demand for hybrid circuits has dropped significantly. It's easier, faster, and cheaper to use surface mount technology. No special clean rooms are needed. No leak tests or leak test machines are necessary. No special designers or assemblers are required. Instead, there are a few straightforward changes in the ordinary through-hole manufacturing process.

Obviously, this leaves many of those specialists in a difficult position. While there will probably always be some demand for hybrids, the supply of specialists is much greater than the need. The pay for those still in the field has dropped and many have not be able to find work in their speciality. They will probably have to get training in some other field to make the money they once did.

Whenever there is a breakthrough, specialists feel the brunt of it. Of course, every breakthrough creates a whole new set of specialists. Vacuum tubes to transistors, transistors to integrated circuits, integrated circuits to ASICs (Application Specific Integrated Circuits). Being a specialist on the leading edge of technology is very rewarding. Being on the trailing edge is another story.

The last problem I want to discuss is usually limited to academic specialization. A researcher often spends his whole career following a single area of interest. What happens if that area no longer stays interesting? What if it becomes clear that the research is just a dead end? Every researcher starts out with great dreams and hopes. It's frustrating and heartbreaking to realize that your life's work really amounts to very little.

Generalization's Good Points

A generalist will rarely be able to compete directly with a specialist. However, a generalist will be able to compete at a high level in a number

of different areas. Often, these areas are wildly different. While many analog engineers can do some RF design and digital engineers can write some software, the generalist will be able to do all these things, along with optics, acoustics, ergonomics, and a half dozen other things. Generalists make very good system managers (if they have the temperament). They can easily integrate different concepts from different specialities.

This means that they will be more attractive to smaller companies than larger ones. This is because a small company can't afford six different employees who can't be supplied with enough work to keep them all busy. However, a single generalist who can wear many hats is very valuable to them. In such situations, the generalist's career can advance quickly.

A generalist never has to worry about being out-dated. He has much experience from many areas to draw from. If the company should fall on hard times, the generalist can usually find other work fairly quickly. The generalist embraces change and always likes to learn and do new things.

The Cons of Generalization

It takes a lot more work to be a generalist than it does to be a specialist. This is especially true in engineering, with so many changes happening every day. Like Alice in Wonderland, you have to keep running as fast as you can just to stay in the same place.

However, this is not really a problem because generalists love to learn. So, while it's certainly work, it's also enjoyable.

Generalists usually make less money than specialists, but often more than the average. This is basically because of job specifications and salary brackets. It's pretty much standard practice for companies to set pay scales depending on the degrees held by the employee. A Ph.D. gets more than a Masters. A Masters gets more than a BSEE. A BSEE gets more than a BSET. There is no mechanism in place for generalists.

Additionally, many firms are concerned about possible employee friction and dissatisfaction if it became known that someone with a BA degree was getting paid more than a BSEE.

There is also a problem regarding credibility with generalists. If someone with a Ph.D. in engineering says one thing and someone else with a BA in psychology disagrees, who would you believe? The credibility of a generalist must be built entirely from his performance. This makes it difficult

for outsiders to see and compare.

Conversely, an advanced degree is easy to rank. This problem stems from the previously noted point that generalists don't follow the typical academic path.

Pretenders and Professionalism

There are those who profess to be a specialist or a generalist, but are not. You see this fairly often in the independent consulting business. In order to get a contract, some people will simply say that they can do things that they have little or no experience in.

For example, a digital designer will agree to design a spread-spectrum receiver. I'm sure that these people actually feel that they can complete the contract successfully at the time.

However, after weeks or months of floundering, it becomes clear to all involved that the job is not going anywhere.

This is bad business. It's unprofessional, costs time and money, makes the customer angry, destroys credibility, and generally gives a bad name to all independent consultants. Whether you are a specialist, generalist, or something in between, it's important to know your professional limitations. Promising more than you can deliver is never a wise thing to do.

The same occurs in business. You tell your boss that you can write the real time DSP software even though your only experience in programming was a COBOL accounting program. This is not to say that people should not learn new things on the job.

Rather, it's about being honest. It's about being honest to your boss (who should have a good idea of your capabilities), but — more importantly — it's about being honest with yourself. This is sometimes a very hard thing to do.

Young, eager, and inexperienced engineers don't always understand that limits are real things. Professional engineering is not at all like school. In school, if you make a mistake, you lose points on your grade. In the real engineering world, if you make a mistake, there are consequences to others. Sales are lost, complaints are made, or people may be injured or killed. Of course it's disappointing, but it's important to see the reasons why you were not chosen to design a nuclear fuel rod retractor as your first assignment in your first job.

Lastly, honesty will actually increase the likelihood of getting a plum task later. You've shown integrity and good self-appraisal by indicating that a job was beyond your abilities. The next time you are asked to do something special that you know you can do well, you will be believed. Honesty is appreciated at all job levels.

Business Specialization and Generalization

Businesses specialize and generalize just as individuals do. The pros and cons are similar, but there are a couple of things to talk about. Smaller technical companies tend to specialize and larger companies tend toward generalization. Most of this is based on economics. It takes more effort (in business this means "money") to generalize because more overhead is needed. More employees are required to handle the numerous technical jobs. More equipment is needed to support these people.

In a company that specializes, a smaller number of employees is usually needed. The equipment requirements are also smaller. While the specific instruments may be more expensive, they number less, so the overall costs are lower. Larger companies tend to generalize because the market base cannot support the revenues needed by the company to survive. However, there are some large companies that are still quite specialized.

It's important to note that generalization and specialization are the endpoints of a single line. There are an infinite number of gradations between these points. Businesses — like people — can be placed anywhere on the line. The focus of this article is to illustrate the concerns and considerations that are faced

when moving along this line. Often times, these topics are not considered. Obviously, this can create problems later.

An example of a large, specialized company is Microsoft. This may seem surprising, but think of what Microsoft produces. It makes operating systems and related software for a single format of computers. True, it makes millions and millions of them and they have a virtual monopoly on many of their software products.

However, if the PC suddenly disappeared and was replaced with some new form of computer, Microsoft would be in very serious trouble. It is also true that this does not appear likely to happen, but vacuum tube designers probably thought something similar just before the transistor was invented. The point is to show the very narrow focus of the company.

Compare this with Hewlett-Packard/Agilent. Everyone knows that they make great test equipment, but they make nearly every type of test equipment imaginable. They also make computer systems, LEDs, optocouplers, fiber-optic components, hospital patient monitoring displays, and on and on and on. (Never forget — or forgive — their calculators that used Reverse Polish Notation.) Clearly, there is a huge difference when compared with Microsoft. It's hard to imagine any single technical advance that would cause problems for Hewlett-Packard/Agilent. They thrive on being at the leading edge of technology. Their test equipment has paved the way for countless advances in many, many different fields.

Generalize and Specialize

It was noted earlier that specialization often occurs very early in a person's academic career. This is the common and accepted procedure. However, it doesn't have to be that way. There is nothing that prevents someone from specializing later in life.

Working for a year or so between high school and college and again between college and a graduate program can be very beneficial. Having real world experience is something that cannot be taught in school. Understanding how a business works first hand can be extremely important in your education. Additionally, you can make better life choices about your speciality if you are exposed to that specialty in action.

Obviously, this is a more difficult path to take, but getting a broad-based education first is useful. If you have a firm foundation in all of the sciences, then you will find it fairly easy to specialize in a number of different areas.

What's more, you will be able to draw on this wide-ranging knowledge. This will give you insights that may not be obvious to others in the field.

While it's fairly easy to specialize later in life, it's very much harder to generalize later. As noted above, a broad-based science foundation is required. This is sort of like remedial learning and few people have the patience or disposition to do this. Being a generalist is really a state of mind and way of life. It's not something you can learn in evening classes.

Conclusion

There's a lot to be said about being a generalist or specialist. Where you choose to be on the generalist/specialist line is up to you, but it's important to know that you are making a choice. Your decisions will affect your life and career. Choose wisely. **NV**

Electronic Theories and Applications From A to Z

Let's Get Technical

Shrinking Bits — A Second Look at Digital Data Compression

Last time, we examined the applications for lossless and lossy data compression methods. In this second look at digital data compression, we will take a look inside these different compression techniques:

- Run Length Encoding
- Dictionary-Based Compression
- Huffman Coding
- Shannon-Fano Coding
- Quantization

All of these techniques provide lossless compression except for the Quantization, which throws away information and achieves higher compression ratios. Let us begin, though, with Run Length Encoding.

Run Length Encoding (RLE) is one of the most simple compression schemes available. In this technique, a single data value and a repeat count replace consecutive data values that have the same value.

Figure 1 shows a simple example. Here, 20 bytes of input data are compressed into 12 bytes of output data. The more the data values stay the same, the greater the compression.

For example, if 255 bytes of data all contain the same value, the RLE data will consist of only two bytes (repeat count and data value).

Dictionary-Based Compression involves building a dictionary of the words (or phrases) used in the text to be compressed. Pointers to the words within the dictionary represent the words from the input text. Frequently used words are only stored once in the dictionary, which is where the compression comes in. Figure 2 illustrates this compression process.

Let's work through an example. Consider the following block of text (which is contained within the input file):

The wheels on the bus go
round and round
round and round
round and round.
The wheels on the bus go
round and round
all day long.

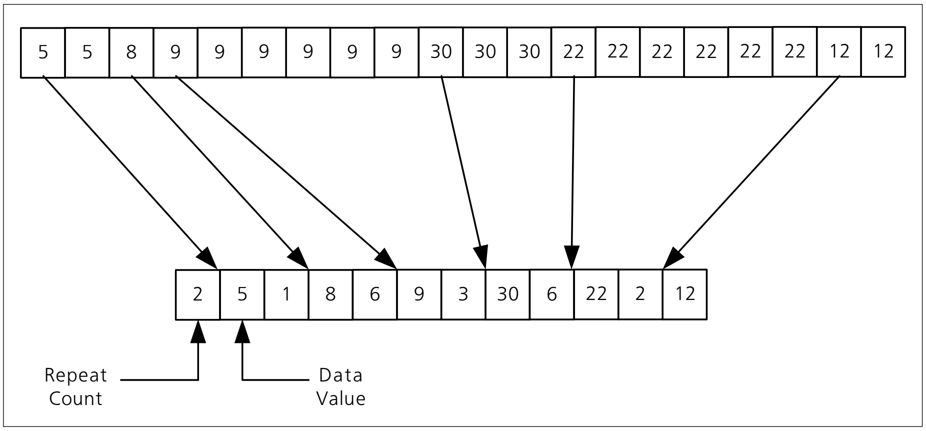
This text contains 136 bytes of data (uncompressed) when saved as an ordinary text file. Do not forget that the newline characters (carriage return, line feed) at the end of each line must also be counted, as well as the spaces between words. The word dictionary created for this input data contains the entries shown in Table 1.

The pointers to the words in the dictionary will be saved as 16-bit (two byte) integers. This allows for 65,535 different words in the dictionary. The pointer stream for the input text looks like this:

1	2	3	4	5	6
7	8	9			
7	8	9			
7	8	10			
1	2	3	4	5	6
7	8	9			
11	12	13			
0					

The 0 pointer at the end indicates the end of the pointer stream. This gives a total of 28 pointers, which require 56 bytes of storage in the output file. Together with the 66 bytes of dictionary text, the output file contains a total of 122 bytes. This is not much of a savings compared to the original 136 bytes of uncompressed data. If, however, the words were longer or occurred more

Figure 1. Using Run Length Encoding to compress data.



frequently, better compression would result. Let's see if this is true by extending words into phrases. Table 2 lists the phrases found in the input file.

The pointer stream for the phrases becomes:

1
2
2
3
1
2
4
0

Now, we only need to store eight phrase pointers for a total of 16 bytes. Together with the 76 bytes of phrase dictionary, we have an output file containing 92 bytes of compressed data — a much larger savings than the word-based method.

Both RLE and Dictionary Compression do their work on-the-fly. Other compression techniques look at the entire block of data before beginning their work. These compression techniques fall into the Statistical category of compression methods.

The first technique in this category is Huffman Coding. In this technique, we build unique binary strings to represent the different data items we encounter. The binary strings typically require fewer bits to store than the original data item.

Huffman Coding begins with information that describes the distribution of different data items within the entire block of data. For example, suppose we have a text file containing 250,000 characters — all of which are either A, B, C, or D — with the percentages shown in Table 3.

Huffman Coding begins by finding the two smallest percentage items (the B and C characters) and combining them into a simple tree structure. The combined percentage (10% plus 15% equals 25%) is now placed back into the list of percentages and the process is repeated until you get to 100%. The data items are placed into the structure so that the lower percentage item is always on the left. Figure 3 shows the tree structure generated using the Huffman technique.

By traversing the tree, we can determine the unique binary strings associated with each data item. Table 4 shows the results of the traversal.

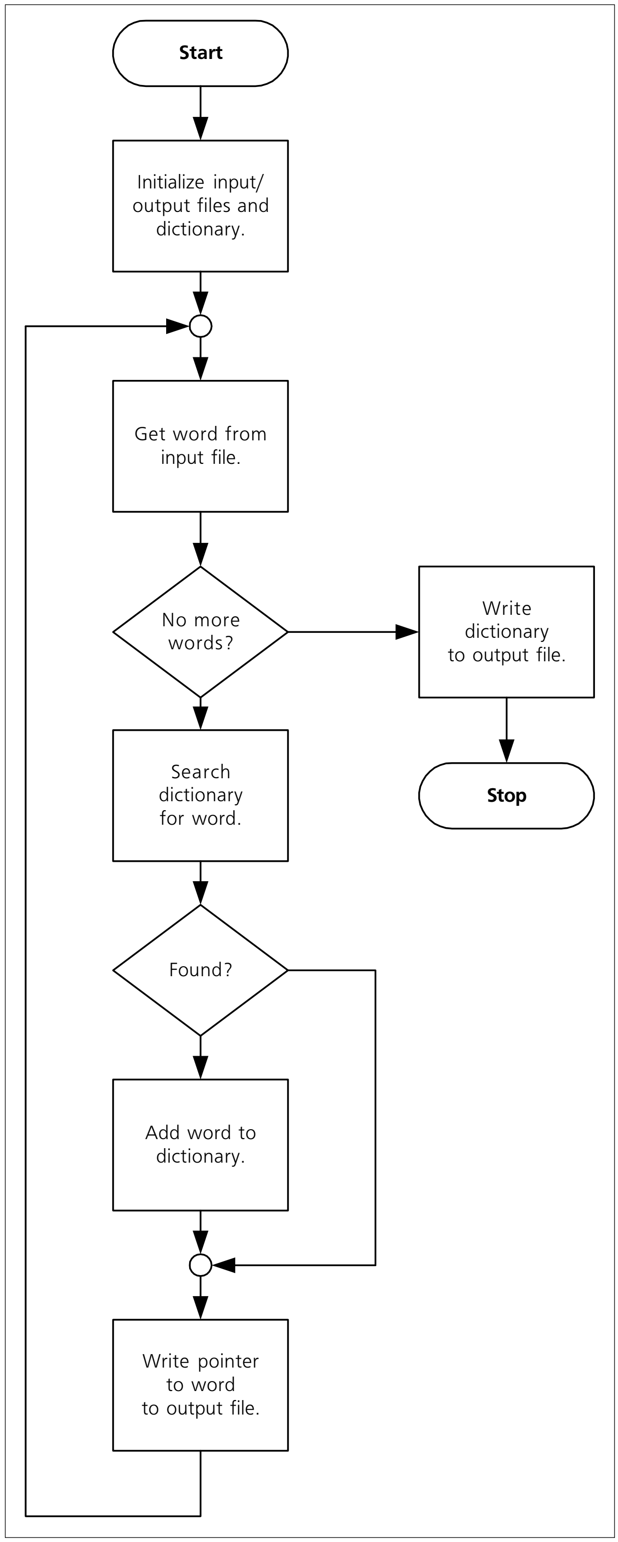
Notice that the data items with the largest percentages have the smallest bit strings. This is the beauty of Huffman Coding.

Word Number	Word	Length
1	The<sp>	4
2	wheels<sp>	7
3	on<sp>	3
4	the<sp>	4
5	bus<sp>	4
6	go<cr><lf>	4
7	round<sp>	6
8	and<sp>	4
9	round<cr><lf>	7
10	round.<cr><lf>	8
11	all<sp>	4
12	day<sp>	4
13	long.<cr><lf>	7
	Total Length	**66**

Table 1. Word dictionary created from input text file.

Knowing the lengths of each bit string, we can easily determine the average number of bits per character required in the compressed file. Table

Figure 2. Operation of the word-based Dictionary Compression process.



Phrase Number	Phrase	Length
1	The wheels on the bus go<cr>	26
2	round and round<cr>	17
3	round and round.<cr>	18
4	all day long.<cr>	15
	Total Length	**76**

Table 2. Phrase dictionary created from input text.

Character	A	B	C	D
Percentage	50%	10%	15%	25%

Table 3. Distribution of data items within input file.

Data Item	Percentage	Bit String
A	50%	0
B	10%	110
C	15%	111
D	25%	10

Table 4. Huffman Coding strings for the four data items.

5 shows the calculations.

Multiplying each percentage by its associated bit string length and adding them up gives a total of 1.75 bits per compressed character. In the original data file, each character required eight bits of storage for a total of 2,000,000 bits.

Now, only 437,500 bits are needed (250,000 characters times 1.75 bits/character), plus a few bits to store the unique strings table and associated data items.

You can experiment with Huffman coding through a simple MSDOS program called HUFF, available for download at **www.sunybroome.edu/~antonakos_j/nutsvolts/huff.exe**

A sample execution of HUFF for the previous example is shown in Figure 4.

The percentages on the MSDOS command line represent, in order, the As, Bs, Cs, and Ds and must add up to 100%.

The Shannon-Fano Coding technique also uses the list of percentages to determine unique bit strings for the individual data items. Instead of building a tree structure, the Shannon-Fano technique simply breaks down the data items into different groups of items, assigning a bit value to each group.

First, the items are arranged in

Data Item	Bit String	Bit Length	Percentage	Bits Required
A	0	1	50%	0.5
B	110	3	10%	0.3
C	111	3	15%	0.45
D	10	2	25%	0.5
			Total	**1.75**

Table 5. Calculations to determine average number of bits per compressed character.

Data Item	Percentage
A	50%
D	25%
C	15%
B	10%

Table 6. Percentages sorted into descending order.

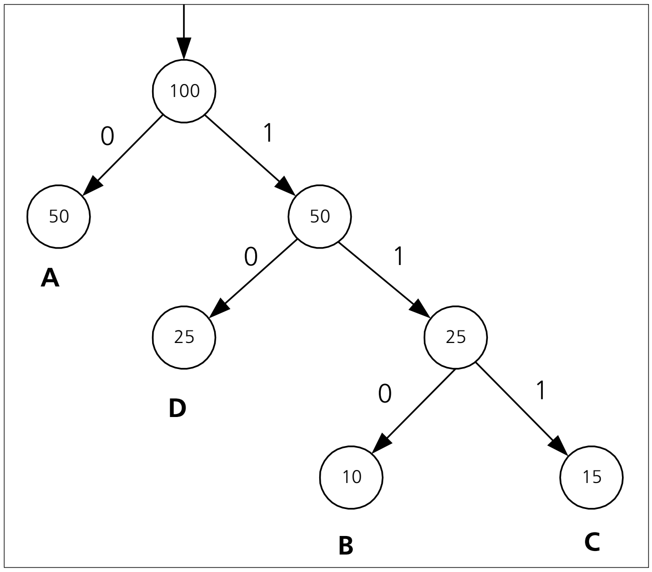


Figure 3. Tree structure containing unique binary strings for each data item.

descending order of percentage, as shown in Table 6.

Next, divide the items into two groups so that each group has roughly the same percentage as the other. One group gets a 0 bit assigned to it and the other group gets a 1 bit. Keep subdividing the groups until there are no more groups to split. Figure 5 illustrates this process.

The unique bits strings for each data item are easily read off Figure 5(c). Note the similarities with the strings from the Huffman Coding example. Are the results the same? If not, are they acceptable? The answers are, "Not exactly," and, "Sure they are!"

Last, we come to our only

```
C:\> HUFF 50 10 15 25

Percentages:
B: 10%
C: 15%
D: 25%
A: 50%
                         |
                         |
       ------------(100)------------
     0 |                          1 |
       |                            |
     (50)            --------(50)--------
      A            0 |                 1 |
                     |                   |
                   (25)           ----(25)----
                    D           0 |          1 |
                                  |            |
                                (10)         (15)
                                 B            C

Unique encoding strings:
B: 110
C: 111
D: 10
A: 0

Compression results:
B: 10% times 3 bits = 0.30
C: 15% times 3 bits = 0.45
D: 25% times 2 bits = 0.50
A: 50% times 1 bits = 0.50

Each character requires 1.75 bits.
```

Figure 4. Sample execution of HUFF program.

lossless technique, buried within the compression algorithm for JPG images and indicated in the flowchart shown in Figure 6.

The compression in a JPG comes from the combination of a Quantizing process followed by RLE compression. An algorithm called the Discrete Cosine Transform (DCT) is used on an 8 x 8 block of pixels from the original image, converting the 64 data values in the block to another set of 8 x 8 DCT values. These new values do not represent pixel colors or intensities any longer. Instead, they represent frequency information caused by the interaction of the pixels. If a reverse DCT is used on the converted data, you would get the original pixels back.

Instead, the Quantizing process divides all the DCT values by an integer, throwing away the remainders.

For example, the following string of data is quantized by dividing all values by 10 and ignoring the remainders:

Input: 212 186 112 67
36 18 11 4
Output: 21 18 11 6
3 1 1 0

Now, when the quantized data is un-quantized (multiplied by 10), we get:

Input: 21 18 11 6 3
1 1 0
Output: 210 180 110 60 30
10 10 0

Let us compare the original eight data values with their un-quantized values:

Original: 212 186 112 67
36 18 11 4
Un-quantized: 210 180 110 60
30 10 10 0

They are all different. Lossy compression does not give us our original data back, but — in the case of the JPG image — this does not matter. The un-quantized values will be passed through the reverse DCT process, giving an 8 x 8 block of pixels that are close to the original block of pixels, but slightly different.

What, only 30 shades of blue instead of 243? Our eyes are not good enough to notice subtle changes in color, which is why we can get away with lossy compression (via quantization) in the JPG image. Plus, best of all, by throwing away the remainders, the quantized data compresses better.

Figure 5. Partitioning the data items in Shannon-Fano Coding. **(a)** Finding the first two groups (A and DCB). **(b)** Splitting the DCB group (into D and CB). **(c)** Splitting the CB group.

(a)

A	50%	0
D	25%	1
C	15%	1
B	10%	1

(b)

A	50%	0	–
D	25%	1	0
C	15%	1	1
B	10%	1	1

(c)

A	50%	0	–	–
D	25%	1	0	–
C	15%	1	1	0
B	10%	1	1	1

Compression Technique	Category and Type	Application
Lempel-Ziv-Welch (LZW)	Lossless, dictionary	TIF image files
Adaptive Huffman	Lossless, statistical	Large files
Delta Modulation	Lossy via quantization	Speech compression

Table 7. Additional compression techniques.

The nature of the DCT is to create values similar to those shown in the example. However, the DCT values get smaller in each new row of the 8 x 8 matrix, which leads to many 0s and other small integers clustering near the bottom right corner of the matrix.

By using a zig-zag technique to read the quantized values out one diagonal at a time, we create a 64 element string of quantized values with many duplicated values grouped together. RLE compression then compacts the string by eliminating the duplicates.

The process shown in Figure 6 must be repeated for every 8 x 8 block of pixels in the image. An image having a resolution of 640 x 480 would contain 4,800 blocks of pixels. The DCT process alone would require over 2.4 million multiplications for all pixel blocks. Just seeing a JPG image appear in a browser is a feat of mathematical engineering.

There are many other compression methods, some of which are listed in Table 7.

Some techniques are easily performed in software while others are easily applied using hardware. Even inexpensive digital cameras have hardware to compress the image data. Search the web for additional compression information and techniques and be prepared to compress the results you get from the volume of information out there. **NV**

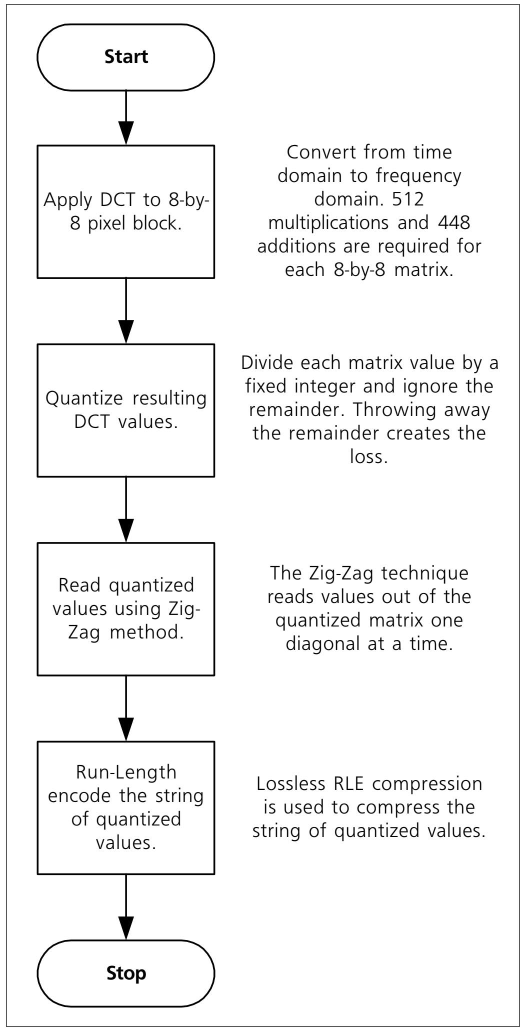


Figure 6. Steps involved in compressing one 8 x 8 block of pixels in a JPG image.

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Approaching the Final Frontier

Near Space

Modifying a PenCam for Use in Near Space Applications

I like to collect data. If I can send a near spacecraft (NS craft) to 100,000 feet and return data on cosmic rays, I'm in heaven (or maybe it's near heaven).

For most people, though, they want to see photographs. To them, your backpacking trip to the bottom of the Grand Canyon isn't interesting unless you can share photographs.

For this reason, you'll want your NS craft to carry a camera. In this month's column, I want to explain how to modify an inexpensive digital camera for control either by a 555 timer circuit or a flight computer. The procedure is the same for other cameras I have modified, so the directions here do not limit you to using inexpensive, low resolution digital cameras.

The camera I modify in this month's column is called a PenCam and is available at Wal-Mart for less than $20.00 (Figure 1). It contains built-in memory and a CCD imager operating at VGA resolution. At high resolution, it has enough memory to store a total of 19 images, but if you set it for low resolution, it then holds a total of 76 images — four times as many. The weight of my PenCam is 1.2 ounces or 60 grams with its two AAA batteries. It's 5" tall, 1-1/4" wide, and 5/8" deep. Its compact design makes it useful for BalloonSats, where weight (and space) is at a premium.

Figure 1. The PenCam (note the AAA cell for scale).

To modify the PenCam, you will need to access the electrical contacts of its two switches and solder thin gauge wires to them. The wires terminate in either a momentary push button switch and NPN transistor or two NPN transistors, depending on your application.

This article will explain how to build a 555 timer to operate the PenCam. An explanation on constructing a flight computer that can operate the PenCam will be covered in a future column.

First, purchase a PenCam and install a set of AAA cells into it. You need to make sure the PenCam works properly and that you can download the images before making this modification.

If the camera does not work, return it because, once you break into this project and violate the camera's warranty, it's too late to return the PenCam if it turns out to be defective.

Now that you know you have a functional camera, it's time to modify it. The function and location of the two switches to be replaced are indicated in Figure 2.

Opening the PenCam

Remove the batteries you used to test the camera and leave the battery compartment cover off. Also remove the pocket clip attached to the camera, since you won't need it. The PenCam body is held together with two small screws and tabs molded into the plastic case. Use a small, jeweler's Phillips screwdriver to remove the two screws located inside the battery compartment. You'll probably want to use a pair of fine tweezers to pick these screws out of the battery compartment.

Set the screws aside where they can't be lost; be careful, they are pretty tiny. Now, work your way around the case and carefully open it without breaking the plastic tabs. I found the top of the case to be the most difficult part to open. When you open the case, you'll see that the camera circuit is contained on a single PCB (Figure 3).

When you open the PenCam, the top button — the shutter button — will fall out. The button is just a chunk of plastic that presses against the micro-switch on the PenCam PCB. Toss the button, as you won't be needing it after this modification.

At this point, you could leave the selector button in place; however, if you do, you must mount the PenCam in such a way that you can access the switch. By installing a remote switch, you have more freedom as to how you can mount the PenCam in a BalloonSat. Next, we'll see how to remove the camera PCB so you can access

the selector switch.

There are three small screws holding the PCB to the camera case. The first is located at the bottom-left of the PCB and the remaining two are on the lens casing. Remove all three screws and set them aside. The lens casing comes off when you remove the last two screws; this exposes the CCD imager. It's a good idea to work in a relatively clean area, so you don't get dust on the face of the imager.

After you remove the three screws, the PCB will lift out of the camera case, as will the selector button. Toss the selector button, as it isn't needed anymore. Use a DMM to determine the proper connections on the two switches before soldering wires to them. Set the DMM to continuity check and probe the four pins on the selector switch.

You should discover that the left two pins are connected together and the right two pins are also connected together. When the button is pushed, the top two pins are shorted together, as are the bottom two pins. If your PenCam is identical to mine, solder wires to the top two pins as shown in Figure 4.

There are only two pins on the shutter switch, so there's no need to determine which pins to use.

Cut four lengths of thin gauge wire, about 12" long. (I used #26 gauge, stranded.) Strip about 1/4" of insulation from one end of each of the four wires. Tin the stripped ends well. Some of the insulation may melt as you tin the wires, so trim the tinned ends to 1/8" after tinning. The ground connection for each switch is the pin of both switches that is located the closest to the center of the PenCam.

Solder each wire by holding the tinned end of a wire in contact with its switch pin and heating it with a well-tinned soldering iron. Solder from the switch pin and the tinned wire will connect the wire to its switch pin. Solder the wires carefully, as the spacing around the switches is a little tight.

To reduce confusion over which wires connect to which PenCam micro-switch, pass the wires for each micro-switch through their respective button holes in the case. So far, you have removed five screws from the PenCam. The longest two mount the lens case to the PCB and the PCB to the back of the camera case. The shortest screw holds the lower-left hand corner of the PCB to the PenCam case.

Before you put the lens case back on, however, take a minute to look at it. From the underside, in front of the lens is an infrared blocking filter. If you remove this thin sheet of glass, the CCD imager will be capable of recording infrared images.

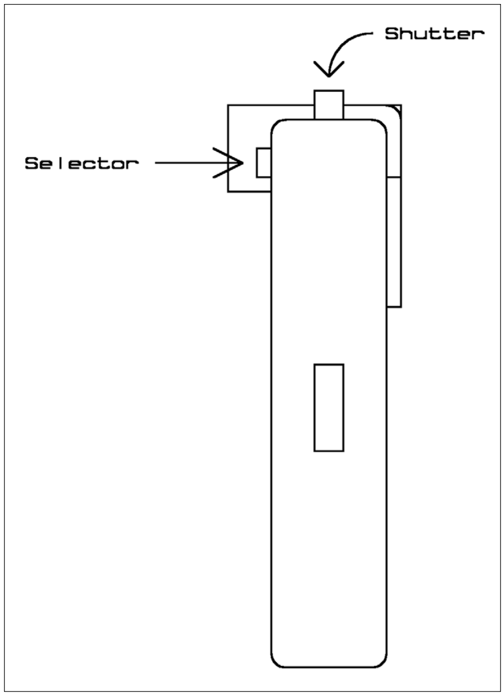


Figure 2. A side view of the PenCam, highlighting the function and location of the two buttons to be replaced.

One experiment you may want to perform in near space is to compare visible and infrared images. Since these PenCams are so inexpensive, you can afford to modify two of them. The first one would have the IR filter intact and the second one would have it removed.

As long as you place the PenCams side-by-side and operate them at the same time, they'll record images of the identical scene. One image would be strictly in visible light and the other image would be in both visible and IR. The differences between the images would be due to IR radiation.

Perhaps the best way to bring out this detail is to invert the visible light image and add it to the IR and visible image. I believe this will subtract out the visible light image from the IR and visible light image, leaving only the image due to IR radiation. How to combine the images and what software

Figure 3. The PenCam on the half shell. The PCB is mounted to the back half of the camera case.

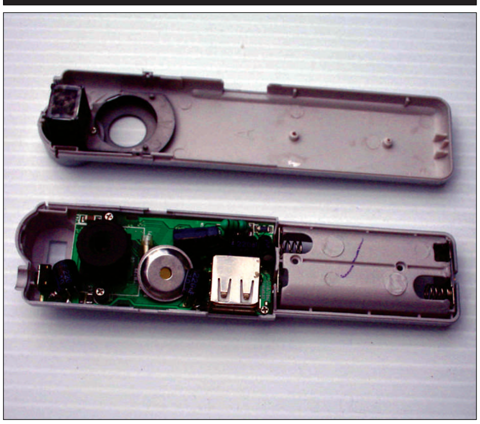
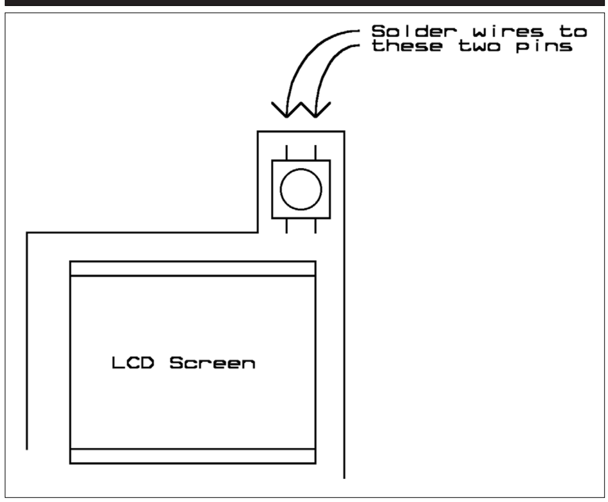


Figure 4. Adding external wires to the shutter switch.



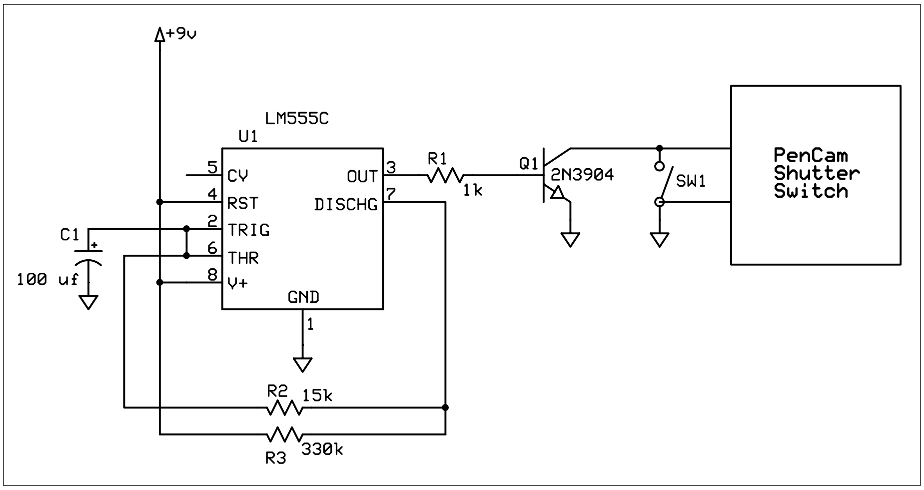


Figure 5. Schematic of the 555 timer-driven shutter switch.

to use I leave as an exercise for the reader. However, if you do work out the details, please contact me and I'll share the process with the rest of this column's readers.

Now, close the camera case. Be careful not to pinch the wires in the case. Test your switch connections once the case is closed. Put two AAA cells into the PenCam. When you tap the two wires from the selector button together, the PenCam should power up and beep.

Assuming this is the first time the camera has been started since the batteries were installed, the LCD should display 19, the remaining number of photographs that can be stored in memory. Next, point the PenCam toward a well-lit scene and tap the two wires from the shutter switch together for about one second. There should be a beep as the camera records an image. Check to make sure that the LCD now displays an 18.

If any of these tests fail, then open the case and look for a loose or misplaced wire. After testing the wire connections, make a strain relief for the wires. Put a small dab of hot glue on the PenCam case and stick the wires to it. Don't place the glue over the button holes or over the seams in the plastic case, as this will make it difficult to fix broken connections in the future.

The shutter button wires will be connected to a NPN transistor. The selector button wires can either be connected to a momentary, normally off switch or to an NPN transistor. If you plan to use the PenCam on a BalloonSat that uses a 555 timer IC circuit to operate the camera, then connect a momentary switch to the selector button wires. If you plan to use the PenCam with a flight computer that will control the operation of the camera, then connect a NPN transistor to the selector button wires.

BalloonSat Connections

Begin by adding the momentary push button. Strip about 1/2" of insulation from the ends of the two selector button wires. Slide short lengths of heat shrink tubing over the wires and then twist the wires onto the lugs of a momentary push button switch. I used a small, RadioShack, normally open, chassis-mounted, push button switch for my remote selector. Solder the connections and cover them with heat shrink tubing.

Next, assemble the 555 timer circuit to operate the camera's shutter button. You'll need a 2N3904 NPN transistor, 1K, 15K, and 330K resistors, 100 µF electrolytic capacitor, 555 IC, eight-pin socket, 9 volt battery snap, and micro-momentary

GPSL 2004

The participants of the Great Plains Super Launch 2004 (GPSL 2004) pose for the camera with their copies of *Nuts & Volts Magazine*. This year, GPSL held two competitions. The first competition challenged participants to reach the highest maximum altitude of GPSL 2004. The second competition required the most accurate prediction for the recovery location of an NS craft prior to launch. Awards for the winners of these competitions were donated by *Nuts & Volts* and Parallax.

First place was awarded to Zack Clobes (W0ZC) of Project: Traveler, whose prediction error was only 5.27 miles and whose balloon reached a maximum altitude of 94,467 feet. Second place was awarded to Rick Von Glahn (N0KKZ) of Edge of Space Sciences for a landing prediction error of 11.44 miles; his balloon reached a maximum altitude of 88,999 feet.

Read more about the participants of GPSL 2004 at their websites:

EOSS
www.eoss.org

HABITAT
http://habtiatskylab.org

NSTAR
www.nstar.org

ORB
http://members.cox.net/hhm_74775/orb/

Project: Traveler
www.rckara.org/project_traveler/

GPSL 2005 will be hosted by Nebraska Stratospheric Amateur Radio (NSTAR) on July 23-24, 2005. All interested individuals are invited to participate. In the meantime, please subscribe to the GPSL Email list under Yahoo Groups for information on this and other amateur near space events.

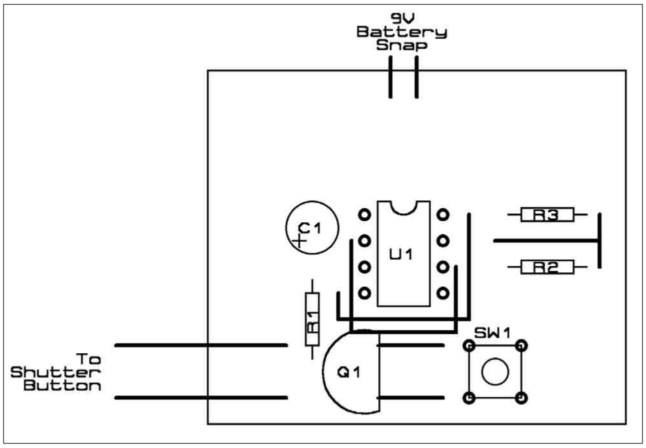


Figure 6. Only electronic components and jumper wires are shown in this diagram. Connections to power and ground are made beneath the perf board.

push button switch (like the ones on the PenCam PCB). I used a 1-3/4" by 3" RadioShack perf board as my circuit board. Figure 5 shows a schematic of the circuit you will build.

Note that both the micro-switch and 555 timer are capable of operating the shutter switch in this circuit. The manual switch allows you to step through the PenCam's menu before you launch the BalloonSat. When you assemble the circuit, use the center two copper strips in the perf board for the power and ground bus. You'll need to cut a few jumper wires to complete the circuit. My layout looks similar to the diagram shown in Figure 6.

Check your soldering and make sure there are no shorted traces. Now, attach the PenCam switch wires to your perf board. The ground wire of the shutter switch is connected to the emitter of the transistor (Q1). The other wire of the shutter switch is soldered to the collector of the transistor. This completes the connections required for a BalloonSat.

I designed this circuit to operate the shutter switch every 43 seconds because the PenCam shuts down if it is not used within a minute of power-up. Check the period of the 555 timer circuit to ensure it pulses in less than 60 seconds. I found that my capacitor was sufficiently different from its printed value that I had to change my R3 resistor (Originally, I wanted to use, 15K, 600K, and 100 µF.).

Your final component values will depend on the variations in the values of R2, R3, and C1. If you look at the output from this circuit, you'll find that the output is high for about 50 seconds and low for about 1 second. This means the PenCam sees its shutter switch pressed for 50 seconds and released for 1 second. My tests show that this is acceptable to the PenCam.

Test the 555 timer circuit and PenCam by first pressing the selector button of the PenCam (to power it up). Next, power-up the 555 timer circuit; this has to be done in less than 60 seconds. You should hear a beep from the PenCam every time the 555 timer circuit goes low.

If the PenCam doesn't record an image (The count on the LCD will decrement every time an image is recorded.), then check that you didn't switch the wires on the shutter switch (ground wire to emitter and other wire to collector). Also, check that pin 3 of the 555 is connected to the base of Q1 and that ground from the 555 timer circuit is connected to the emitter of Q1. Be sure there is sufficient light, otherwise the PenCam will not record an image (but it still beeps).

To change the resolution of the PenCam from high to low, start the PenCam by pressing the select button. Now, press the button an additional seven times. On the seventh press, you'll see a tiny "LO" displayed on the left side of the LCD. When you see that, press the shutter micro-switch on the 555 timer circuit to change the PenCam to low resolution. Afterward, the LCD displays a 76 — the number of images that can be stored in the PenCam's memory.

If you do not remove the

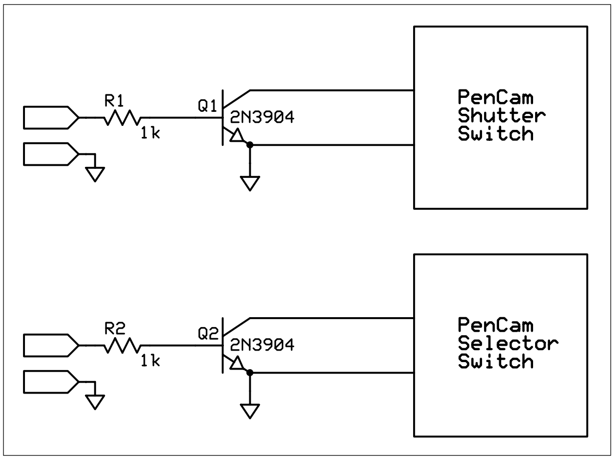


Figure 7. Using transistor switches controlled by the BS2P.

PenCam's battery, then it will remain in low resolution mode the next time it powers up. You can force the PenCam to shut down by pressing the select switch once after the PenCam powers-up. The LCD will display "OF" for off. Press the shutter micro-switch once to shut off the PenCam.

Alternately, you could just wait a minute and the PenCam will shut itself down. Skip to the section "Installing Remote Batteries" if you're not interested in driving the PenCam via a microcontroller.

Flight Computer Connections

I want to thank my student, Jeff Eggebrattan, for testing this modification for the PenCam; originally, I was using reed relays to operate the PenCam. For operation by a flight computer, each switch is connected to a 2N3904 transistor. You need two 2N3904 transistors and two 1K resistors for this circuit (Figure 7).

Connect the grounded wire of each switch to the emitter of a transistor and remaining switch wire to the collector of the transistor. From the flight computer side, connect the flight computer ground to the transistor emitters and an I/O pin to the base of each transistor. Place a 1K resistor in series with the base of each transistor to limit the current to the base to 5 mA.

Terminate these wires as appropriate for your flight computer. Double check that you connected the emitter of each transistor to ground on the flight computer and the base of each transistor to an I/O pin of your flight computer. Now, when the I/O pin of the flight computer's microcontroller is set high, the transistor saturates, shorting the connections of the switch connected to it.

Operating the PenCam With a BASIC Stamp

I programmed my flight computer to power-up the PenCam and then run through the PenCam settings (Listing 1). After "scrolling" to low resolution mode, the flight computer operates the shutter button to change the camera resolution. (In this program, I'm assuming the batteries were initially removed from the PenCam.) One minute after recording an image, the PenCam shuts down. From there, the flight computer only needs to turn on the PenCam and then make it record another image.

You can modify this code to order the PenCam to shut down, rather than wait for it to time out. To do this, operate the selector button once, followed by the shutter button after recording an image.

Listing 1. A simple image acquisition sequencer.

```
'{$STAMP BS2p}
'****************************************
'* Program selects the low resolution   *
'* mode of the PenCam and then records *
'*            three images              *
'*                                      *
'*    L. Paul Verhage 22 Jan 2004       *
'****************************************

powerSwitch    CON 0          'I/O pin of power switch
shutterSwitch CON 1           'I/O pin of shutter button
pushButton     VAR Nib        'Counter to control number of button pushes

Digital_Camera:
  PAUSE 2000
  DEBUG "Select Camera Setting", CR
  FOR pushButton = 1 TO 7     'Push power button seven times for low resolution
mode
    HIGH powerSwitch
    PAUSE 1000
    LOW powerSwitch
    PAUSE 1000
  NEXT

  DEBUG "Take Three Photos", CR
  FOR pushButton = 1 TO 3
    HIGH shutterSwitch
    PAUSE 1000
    LOW shutterSwitch
    PAUSE 5000
  NEXT
END
```

Installing Remote Batteries

The final modification is only necessary when the space available for the PenCam is tight

or if the PenCam is to be exposed to cold temperatures and you want to keep the battery warm. In this modification, the battery compartment is cut off (Talk about really violating the warranty!) and a remote AAA cell holder is attached.

You can use any battery combination to operate the PenCam, as long as it has a voltage of 3 volts. I stayed with AAA cells because my BalloonSat doesn't have the room or weight allowance for AA cells. I used a RadioShack two AAA cell holder for remote power.

Remove the two AAA cells from the PenCam. With a small saw — like a coping saw or Exacto saw — cut the bottom of the PenCam case off. Leave the top of the battery case and the two metal contacts in place on the PenCam case. This modification shortens the PenCam by about 2".

I recommend re-tinning the bare ends of the AAA cell holder's wires. Tin the positive power pad of the PenCam. Solder the red and black wires of the new cell holder to the metal contacts of the shortened PenCam. Connect the cell holder's red wire to the flat contact in the PenCam and the cell holder's black wire to the spring contact of the PenCam.

I twisted the black wire around a wire in the spring of the negative power coil and then soldered it in place. Install the PenCam's battery and test it again.

For strain relief, I recommend using a little hot glue to glue the wires of the remote power to the body of the PenCam. Don't apply glue to the soldered contacts, as that will make it difficult to fix a broken solder connection should it happen in the future.

There's one warning about the PenCam. Do not remove the battery from the PenCam before downloading its images. The PenCam does not have a non-volatile memory, so removing the battery erases your images from the PenCam's memory.

Onwards and upwards,
Your Near Space Guide **NV**

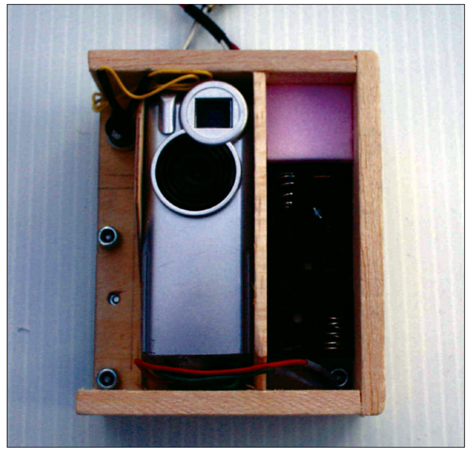


Figure 8. The PenCam pallet of my BalloonSat. Note that the battery holder for the remote power is located to the lower right of the shortened PenCam.

Tech Forum

QUESTIONS

Does anyone know of a source or replacement for a 95H0359 180 MHz triple OR/NOR gate IC? It was used in a Heathkit IB-1103 frequency counter, part number 443-79.

#11041 **J. Sweeny**
via Internet

I am looking for a supplier or voltage specs for batteries for a Juno Model 4RJ-7 Geiger Counter. The battery codes are: E12, TR113,TR115, and 413.

#11042 **John Kleber**
via Internet

I volunteer for a small theater that has about six small mics. I would like to build some small transmitters and a six-way receiver array in one package. Of course, all would have different frequencies and would need to hook into a sound system. I would like for it to be simple and to have a range of about 100 feet.

#11043 **Dale K. Weakley**
via Internet

I need a variable speed PWM controller that can drive a brushed DC motor at 48 volts (or higher) and at about 200 or 300 amps. Is there, perhaps, a kit? It's for an electric bike.

#11044 **Patrick Rask**
via Internet

I'm trying to repair an RCA 25" TV, manufactured April 2002. It is model #F25442, chassis #CTC-203A09. The TV is completely dead and will not make a sound! The fuse is fine (never shorted), B-voltage is present, and the flyback, horizontal driver, powerline regulator, resistors, and caps appear to be okay. Any answers would be appreciated!

#11045 **Matthew Martin**
Alliance, NE

I have a small, 110 VAC, 1500 W hot water tank heater in a seldom used bathroom. I would like to add a push-button control to turn it on only until its thermostat kicks off. Ideas?

#11046 **Anonymous**
Biloxi, MS

I am trying to find any articles on building a DC accumulating ammeter, similar to an AC watt/hour meter. It will be used to monitor the charge/discharge of an "off the grid" home power source.

#11047 **Banjo Ben**
via Internet

My septic system has a pump that pumps gray water out to my septic field, but I can't tell if (or when) it runs. A pump failure will flood my basement with sewage. Is there a simple AC current-sensing circuit (good for about 5 A) that I can attach to some form of indicator that will tell me that the pump has run and for how long? Maybe there is a device that will give a day and time stamp when it runs?

#11048 **Wade Hale**
via Internet

This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

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ANSWER INFO

• Include the question number that appears directly below the question you are responding to.
• Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address if responding by email or we can not send payment.
• Your name, city, and state, will be printed in the magazine, unless you notify us otherwise. If you want your email address printed also, indicate to that effect.
• Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

QUESTION INFO
To be considered

All questions should relate to one or more of the following:
1) Circuit Design
2) Electronic Theory
3) Problem Solving
4) Other Similar Topics

Information/Restrictions

• No questions will be accepted that offer equipment for sale or equipment wanted to buy.
• Selected questions will be printed one time on a space available basis.
• Questions may be subject to editing.

Helpful Hints

• Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
• Write legibly (or type). If we can't read it, we'll throw it away.
• Include your Name, Address, Phone Number, and Email. Only your name, city, and state will be published with the question, but we may need to contact you.

ANSWERS

[8041 - August 2004]

I need an IR circuit to connect to the COM port of my PC, which is running Windows XP. I am using a Timex Ironman 10 alarm watch, which can be programmed via an IR port. Normally, it will work using Windows 98/Me (but not XP) using the monitor screen to send data to the watch. Can anyone help?

The big thing that's getting you is the fact the Microsoft "virtualized" access to devices — such as serial ports — with the release of Windows

2000 and beyond. Older software wanted to directly access the port, but that is now nearly impossible to accomplish. I have two suggestions.

First, download and install the latest version (2.01) of their software from **www.timex.com/html/data_link_software.html** if you are not already using that version. Second, the Timex website requires Windows XP users to run the software in compatibility mode. This is accomplished easily. Navigate to where your program icon is — either on the desktop or the start menu. Right click on the icon and select the properties menu, found at the bottom of the list. On the properties window that comes up, left click on the compatibility tab and click in the box that is next to the phrase “Run this program in compatibility mode for:” and select Windows 98 in the list box below it. Click “OK” to get out of the properties tab and then try running the software.

Thomas Homan
Globe, AZ

[8043- August 2004]

I live in a rural area in a fairly well-shielded building. Cell phone signals are sporadic inside, except when I am very near windows. Are there any proven passive antenna relay systems that work (antenna outside coupled to something in the attic) or something relatively simple that I can construct? I'm not positive, but I believe that service here is still only on the 800 MHz band.

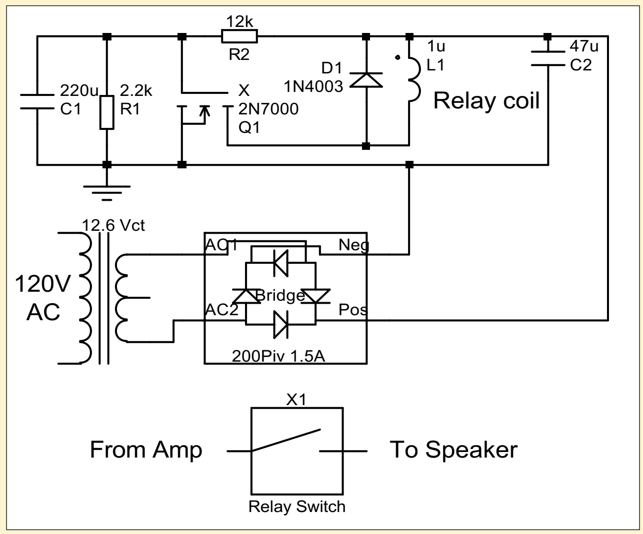
Have a look at **www.cellantenna.com/repeater/building_repeater.htm** for building indoor cellular repeaters depending on your building size and budget. If you Google “cell phone repeater,” a large list of vendors comes up. I'm sure there would be several very high hurdles to jump through for home-built kits/plans if any are available — namely, FCC certification for the device transmitting in the cellular spectrum. The passive relay system is really only for getting the signal through glass to an exterior antenna — like on a vehicle mount — since there is no power to amplify the signal.

As an alternative, you might be able to purchase the car kit for your particular model of phone and lengthen the antenna cable to get it outside the building. The only downside to this would be having a

[9043 - September 2004]

Does anyone have a simple circuit for taming the turn on thump from the charging of the output coupling capacitor of a bass guitar amp that uses a single 90 volt supply?

I actually dealt with a similar issue with an old Peavey PA amp. It would pop pretty hard on turn on and turn off. I tried a few simple/cheap designs, but never quite got the results I was looking for. Finally — after wasting too much time — I settled on a circuit that was independent of the power amps' circuits. Basically, I added a circuit 12.6 V transformer tapped in after the amp's power switch, a delay circuit, and a relay on the amp's output going to the speaker.



The design uses a 12.6 V transformer to a bridge rectifier (a diode would work, too). I kept C2 small so the relay would turn off quickly, then R2, R1, C2, and Q1 form a simple delayed switch. You might need to fiddle with values, depending on the relay and the delay needed, as this gives me about a 3 second delay.

Brandon Spivey
Nashville, TN

fixed location for calls.

Thomas Homan
Globe, AZ

[8042 - August 2004]

I need a circuit to transmit and receive a laser signal to detect small, non-moving objects over 100-150 yards away from a portable power supply. The circuit should be able to determine the range to the object and display it during daylight periods.

While I don't have any circuitry, I can point you to one of the most clever ideas I've seen in recent years. It uses a laser that turns itself on and off as it receives its reflected signal. The distance is inversely proportional to the oscillation frequency and can be measured with a simple frequency counter. Let me elaborate a bit.

Initially, assume that the laser turns on at time t=0 and there is no reflected signal at the receiver collocated with the laser. After a time t1=2x/c, where x is the distance to the object and c is the speed of light, the leading edge of the laser "pulse" hits the photodiode, triggering circuitry that turns the laser off. As long as laser light is hitting the photo diode, the laser remains off.

When the leading edge of the laser pulse hits the photo diode, the trailing edge is just leaving the laser. The trailing edge will hit the photodiode also t1=2x/c after it leaves the laser, and the arrival of the trailing edge at the photo diode (hence, the laser light stops) triggers the laser back on! This oscillation continues as long as the laser is lined up with the target. The frequency of oscillation is f=1/[(2x/c) + (2x/c) + td], where td is the propagation delay of the turn on/turn off circuitry. Measure this frequency and you have the distance.

As an example, assume the target is 100 yards away (300 feet). For simplicity, assume light travels at 1 foot per nanosecond. Therefore, (neglecting for the moment the

[8044 - August 2004]

I need a simple circuit where an LED would indicate if a phone line was busy or not without putting the line off-hook while doing this during an incoming ringing cycle.

#1 The two sides of a telephone line are called Tip and Ring. The telephone company puts -50 volts DC on the Ring and grounds the Tip when the line is idle. You can verify this with a voltmeter.

To make a simple detection circuit, simply connect a PNP transistor as follows:

- Collector through an LED and series resistor to a negative power supply.
- Emitter to ground.
- Base through a 1 meg resistor to the Tip side of the telephone line.

When the Tip side of the phone goes from ground to negative

voltage due to the phone line being taken off hook, the negative voltage will bias the transistor to conduct, causing current to flow through the LED.

It should be noted that, when a line is off-hook, both sides will be negative with respect to ground. This can be verified with a voltmeter.

John Reed
Richardson, TX

#2 RadioShack sells exactly what you want for less than $10.00 — part number 430-0443.

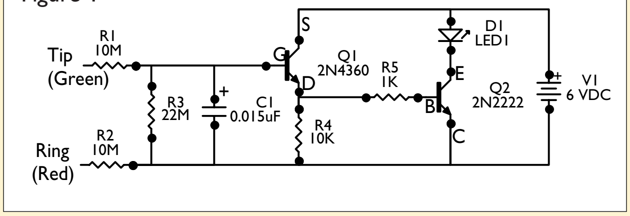
John Herro
Cincinnati, OH

#3 I found this link on the web. It has a simple circuit to flash an LED when the phone line is in use. **www.techlib.com/electronics/telephone.html**

Daryl Rictor
via Internet

#5 Figure 1 is a rather simple circuit. It works on the principle that telephone lines drop to less than 10 V (from about 48 V). This will cause Q1 to turn on and will also turn on Q2. When the transistor turns on, it will allow current to flow through LED1. It can be plugged in anywhere in the house. You need to power the circuit with 6 VDC (two AA batteries, for example).

Figure 1

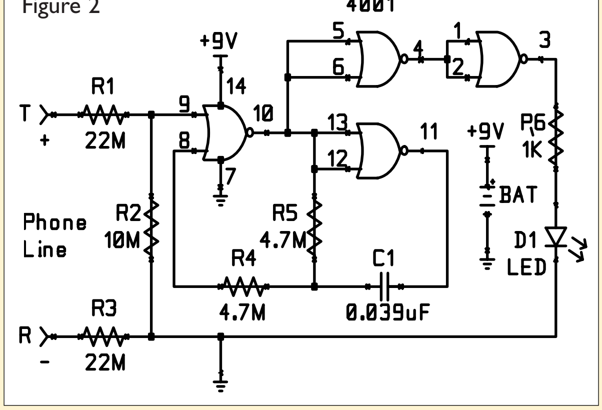


Martin Menard
Kanata, Ontario,
Canada

#4 Figure 2 should be just what you want. Use a 9 V battery for the power supply. Connect the ground to the battery only. The DC resistance across Tip and Ring is so high that the ring generator in the central office should not detect any load.

Larry Moreland
Boring, OR

Figure 2



propagation delay, td), the frequency of oscillation is about (1/600 nsec)~ 1.666 MHz — easily measurable with almost any frequency counter.

To measure the propagation delay, simply place the target at a precisely known distance, measure the frequency, and solve for td.

Of course, I've oversimplified things here, and the devil is in the details. For example, in an outdoor environment, the propagation delay may vary with temperature. Similarly, you will probably need a retroreflector on the target and some kind of collimating optics on the transmitter, along with collecting optics on the receiver, probably with some laser line spectral filtering, but you get the basic idea.

Steve Bepko
via the Internet

[9045- September 2004]

I do quite a lot of 35 mm motion picture projection work and I wonder how close to 24 frames per second the projector is actually operating. Is there a circuit for some sort of sensor that I can hold in front of the lens and measure the FPS count?

First, some key hints: There are two "flashes" per frame from standard projectors to reduce apparent flickering. They also tend to use a motor that synchronizes with the input power line. Thus, a US 60 cycle (Hertz) motor will be geared, etc., for 24 frames per second operation, as would a European 50 cycle (Hertz) driven projector. In the US, the long-term accuracy is excellent in order to keep mechanical clocks accurate. Short term (hours), it can be off by as much as 5% in some areas.

When converting to NTSC (US) TV, the standard is to repeat every fourth frame to get 30 frames from the 24 frames of film. Conversion to the European TV standards is typically done by running the film at 25 frames in place of the 24 frames! The exception is for some news or documentary footage that is shot at 25 frames for direct conversion/ airing.

Now to deal with the device at hand: a counter, an accurate time base, and a sensor. There are a number of RPM counters that work by counting the light flashes as the source is interrupted by fan blades. One of those set for a two blade fan should report 1,440 RPM=24 frames per second, times 60 seconds. If it has no two blade setting, try a four blade setting and expect a 720 RPM reading. (Three blade settings should give a 960 RPM reading.)

Compare the accuracy to the power line. Point the RPM reader at a fluorescent light. Two flashes per cycle, times 60 cycles per second, times 60 seconds per minute = 7,200 flashes per minute. Divide by the number of blades that the RPM counter is set for.

Jerel Arbaugh
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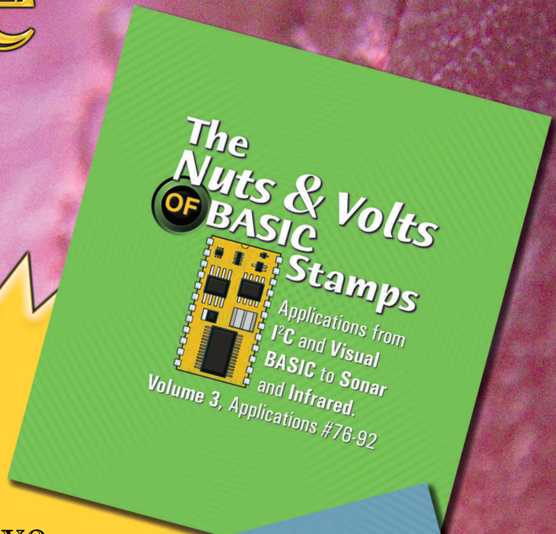

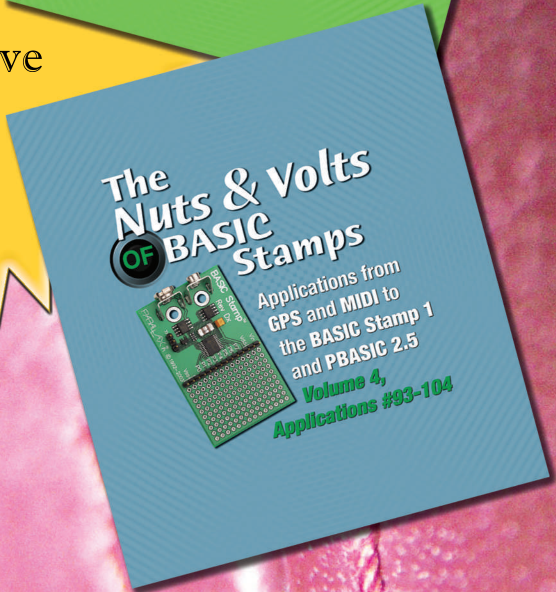

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